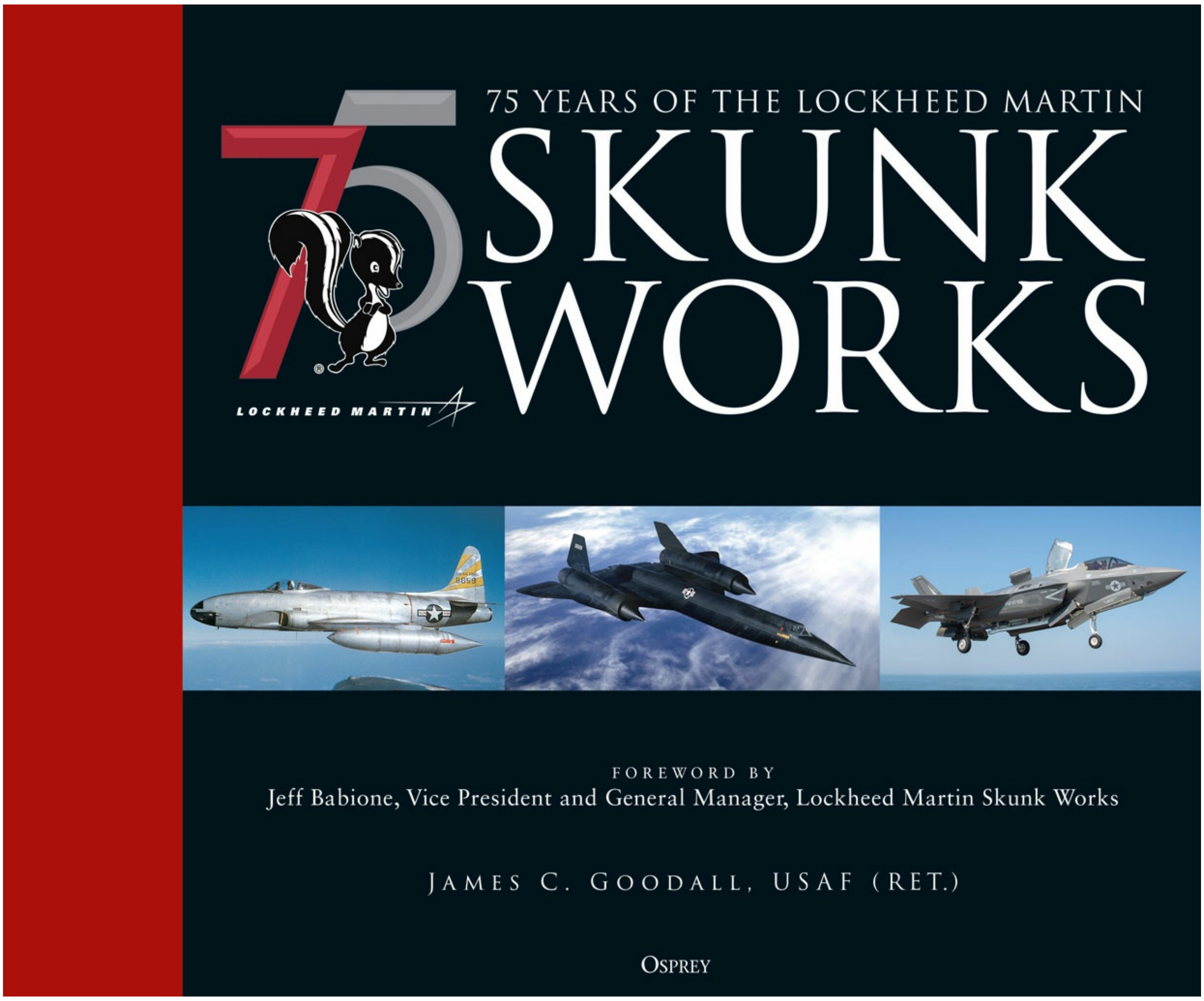

75 YEARS OF THE LOCKHEED MARTIN

SKUNK WORKS

75
LOCKHEED MARTIN

FOREWORD BY
Jeff Babione, Vice President and General Manager, Lockheed Martin Skunk Works

JAMES C. GOODALL, USAF (RET.)

OSPREY

75 YEARS OF THE LOCKHEED MARTIN

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This book is dedicated to everyone that ever worked at the Skunk Works and built
these incredible machines.
Thank you from America

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DEDICATION

IN HONOR OF MY FRIEND

For the sake of clarity, Mr Ben R. Rich, retired President of the famed Lockheed Martin Skunk Works, and I were longtime pen pals, as he liked what I did and we spoke to each other at least once a quarter or so over 25 years. Ben is also the reason the Minnesota Air Guard was blessed in getting not just any Blackbird, but an A-12 Oxcart, serial number 60-6931/128.

Just a few days before Christmas 1994, I called Ben while he was at USC Medical Center fighting a losing battle with esophageal cancer, to see how he was doing. We were talking about all things Skunk Works and about my late friend from Testors, John Andrews. Ben then made a statement that will forever be burnt into my brain. After asking about things like Aurora, UFOs and such, Ben made the following statement (this is a direct quote from Ben's mouth to my ears ...):

> Jim, we have things out in the desert [not referring to Area 51] that are 50 years beyond what you [referring to me] can comprehend, not what you think you could make in 50 years, but what you could comprehend. Jim, if you've seen movies such as Star Wars or Star Trek, we've been there, done that, or decided it wasn't worth the effort.

I asked Ben if he would expand on what he just said. His answer was typical Ben, it was just a simple ... "No." He passed away a few weeks later.

Rest in peace my friend ... Jim Goodall

Ben Rich standing in the cockpit of SR-71A, 61-7955/2006 at Air Force Plant 42, Site II. (Lockheed Martin)

Jeff Babione, Vice President and General Manager of the Lockheed Martin Skunk Works. (Lockheed Martin)

FOREWORD

For more than 75 years Lockheed Martin Skunk Works® has been doing what it does best, enabling our customers' most challenging missions by creating amazing aircraft and advanced technology solutions. Just the name Skunk Works conjures up images of doing things differently and to those in the Aerospace and Defense industry, the name is iconic. From the XP-80 to the U-2, SR-71, F-117, F-22 and now the F-35, our team has designed aircraft that are the pinnacle of innovation and performance.

Created by the talented engineer Clarence "Kelly" Johnson at the age of 33, the Skunk Works has a distinct culture based on 14 rules. These rules outline a way of working that Kelly devised to rapidly address urgent national needs with simple approaches accomplished by small, empowered teams. These rules are foundational and created an approach that is often imitated, given that it yields such notable results. In fact, our work has been recognized, with eight of the 20 annual Collier trophies awarded to Lockheed Martin. The Collier is the Academy Award of the Aerospace and Defense industry. Our past accomplishments are a source of great pride for all of us who work here or have been a part of this team over the years.

Today we are in a period of significant growth, fueled by the same culture and beliefs that Kelly established in 1943. I believe that he is smiling as he looks at what we are up to. We continue to enhance our country's intelligence, surveillance and reconnaissance (ISR) capabilities with new and sophisticated payloads on the venerable U-2, as well as developing cutting-edge technologies and new aircraft that Kelly could only have imagined. We are driven by the same type of urgency that led to the rapid development of the U-2, SR-71 and F-117. We continue to advance fighter technology and I'm particularly excited about our work in hypersonic systems.

Kelly understood the inherent value of speed. The SR-71, which in my opinion was his greatest accomplishment, remains the fastest manned airbreathing aircraft ever developed. Our team at the Skunk Works is hard at work maturing technologies that will take us well past the SR-71's speed, to speeds of more than Mach 5 and above. I predict that hypersonic platforms will change the way our nation fights, much as stealth did in the early 1980s with the fielding of the F-117.

The journey through the decades has not been easy, but as did Kelly, each Head Skunk has found a path that preserved the core of the Skunk Works while adapting to the environment of the times. I'm very grateful to all the leaders that have been at the helm of the Skunk Works, they have left a remarkable legacy. Today, changes in acquisition policy and the rate of innovation, even the source of innovation, have changed the way in which the Skunk Works operates. Make no mistake, we too are always adapting, leveraging the legacy to carry on what Kelly started. Unfortunately, given the classified nature of much of our work, you may have to wait until the 100th anniversary edition to find out what we are really up to!

For now, Jim has focused on sharing pictures that capture the last 75 years of Skunk Works. He has been a fan of the Skunk Works for much of his life. I share his passion for the amazing aircraft we create and the unique culture that allows us to work quickly and quietly to enable urgent national needs. On behalf of the many generations of Skunks, it is my distinct honor to thank Jim for sharing our story with you. I hope you enjoy!

Jeff Babione
Vice President and General Manager of the Lockheed Martin Skunk Works

An F-35B Lighting II lands on the flight deck of the amphibious assault ship USS *Wasp* (LHD1) on 18 May 2015. (USMC)

INTRODUCTION

The Skunk Works of the Lockheed Martin Aeronautics Company was born out of need and vision. In the waning days of World War II, the Axis power of Nazi Germany was producing advanced technology weaponry that far exceeded the capabilities and even the foresight of the Allied war machine. Threatening our bomber fleet was a jet-powered fighter 150mph faster than our fastest propeller-driven fighter. Should the war drag on, the superior performance of this new weapon threatened Allied supremacy of the air. A countermeasure was necessary – a jet fighter of our own. The response to this threat was met by the vision of Lockheed's Clarence L. "Kelly" Johnson.

Using a previously unseen style of project management and organization that is still used as a benchmark of productivity within the government and commercial industries today, Kelly assembled and empowered a small team tightly focused on the creation of America's first operational jet fighter. A dedicated project area was constructed of sheet metal and canvas next to Lockheed's developmental wind tunnel. Management, engineers, mechanics and the airplane were mere steps from each other, providing the shortest possible lines of communication. There was limited understanding in the industry of how to create a jet fighter and there was no time to waste in creating it. It had to fly faster in level flight than the P-38 could achieve in a dive, where it suffered severe stability and control problems. It had to use jet fuel (kerosene) instead of aviation gasoline, which impacted materials for sealing. High-efficiency jet induction and exhaust designs were required. Those challenges did not stop Kelly and his team in Burbank – they became the Skunk Works.

The Skunk Works has had several names over the last 75 years. Early on it was called Lockheed Advanced Development Company, and it is also known as ADP, which stands for Advanced Development Project. The Skunk Works was always located at their Burbank site until they moved the operation to Palmdale, CA at Air Force Plant 42, Site 10.

In 143 days, the P-80 Shooting Star jet fighter emerged from concept to flying reality. It was accomplished in complete secrecy.

The Skunk Works performance on the XP-80 was just the beginning. On each successive project the team carried a set of common traits with the mantra "quick, quiet, quality." Skunk Works aircraft were developed in a fraction of the time and for a fraction of the cost required by the rest of the industry. The projects successfully maintained secrecy despite the fact that thousands of people from Lockheed Martin and its suppliers were involved.

Each new product represented a technological leap that the industry would consider impossible.

The U-2 Aquatone spyplane, developed in only nine months and for less than $20 million, provided President Dwight Eisenhower with the knowledge that the perceived lead that the Soviet Union publicly boasted in missiles and bombers was inaccurate. The photographs from the U-2 proved that Soviet technologies had serious shortcomings. Richard Bissell of the Central Intelligence Agency (CIA), father of the U-2, clearly defined the value of the aircraft when he stated that the U-2 alone was responsible for 90 percent of the hard intelligence gathered on the Soviet Union. This information allowed the President to cut and hold the defense budget to $40 billion (from a 1952 level of approximately $55 billion), despite the cries of protest from Congress and the American public. Inflation during this time was held to 1 percent. This would have been an impossible task if the United States had entered an arms race – especially a race that didn't need to be run.

The record-holding A-12 Oxcart and SR-71 Senior Crown Blackbirds developed in the early 1960s increased the United States' abilities to watch troublesome parts of the world with impunity. Hundreds of missiles and aircraft were launched to intercept the Blackbirds while they flew at three times the speed of sound. Not one succeeded. Virtually every technology on the Blackbird had to be invented, from the stealth design techniques and materials, to the pressure suit that allowed the pilot to survive at the fringes of space, to the structure that experienced temperatures over 600 degrees Fahrenheit.

In the early stages of concept development for the Blackbird, the Skunk Works determined that the original technology path chosen was not viable. Kelly returned the remaining contract dollars to the government rather than wasting it on an invalid solution to a national issue. His action clearly defined the integrity and fiscal responsibility of the Skunk Works team.

As an extension to the Blackbird's mission capability, in 1964 the team developed the D-21 Tagboard/Senior Bowl, a stealthy unmanned spy plane that flew thousands of miles at Mach 3.3. This design removed the risk of a

US pilot being downed in enemy territory while preserving the ability to peer deep into enemies' secrets.

While many of the missions of these aircraft and the direct result of actions taken using the knowledge gathered are still secret, each one contributed immensely to the ability of the United States to shape international policy and an internal defense strategy from data rather than by speculation.

Building on the stealth technology of the Blackbirds, the first very low-observables aircraft, Have Blue, was created in only 19 months in the late 1970s under the leadership of Kelly's personally selected successor, Ben Rich. The reduction in radar cross section and the resulting increase in survivability against the Soviet surface-to-air missiles was almost beyond comprehension. The Have Blue experimental aircraft proved that it was possible to "teach" an aircraft, shaped by stealth instead of aerodynamics, to fly using emerging flight control computers, when it would otherwise tumble uncontrollably. The total cost of the program was $43 million.

The success of the development of the Have Blue demonstrators led to the award of a contract to develop a stealth fighter less than a year after the first flight of Have Blue. In 32 months, the first F-117A Nighthawk took to the skies in 1981. The development program for this revolutionary aircraft cost $773 million – only two-thirds that of the F-16 development, which was underway at the same time. The Nighthawks operated in absolute secrecy for eight years.

When Iraq invaded Kuwait in 1990, President George Bush ordered a massive deployment of offensive and defensive hardware to protect other Persian Gulf states against Saddam Hussein's aggression and forcibly remove him from Kuwait if diplomacy failed. Saddam remained undeterred. During the 1991 Operation Desert Storm, F-117A Nighthawks "kicked down the door" of the Iraqi defenses, one of the most formidable air defense systems in existence at the time. With the Iraqis blinded by the Nighthawk strikes, a flood of Allied aircraft eliminated enemy targets with only a fraction of the friendly losses envisioned by American commanders. It was positive proof to all skeptics that the Skunk Works' stealth technology worked.

When North Korea threatened to develop nuclear weapons in the 1990s, President Bill Clinton publicly deployed the Nighthawks to the peninsula as a show of intent and resolve. The North Koreans returned to the negotiating table.

The Nighthawks also represented a fundamental change in combat systems design – the next generation of fighters, cruise missiles, surface ships and other systems incorporated stealth technologies. Lockheed and its Skunk Works teamed with General Dynamics and Boeing to create the first supersonic low-observable fighter, the YF-22. The F-22A Raptor, as the production version is known today, embodies speed, stealth and lethality in a combination that keeps the United States Air Force (USAF) in a position of air dominance as sophisticated weapons spread throughout an unstable and dangerous world.

To complement the F-22A, the Skunk Works designed and prototyped the first supersonic, vertical landing stealth fighter capable of meeting the multi-role fighter needs of the USAF, Navy and Marines as well as the Royal Navy. Designed to replace numerous aircraft, the Joint Strike Fighter (F-35A/B/C) adds the attributes of affordability and multinational interoperability.

Interspersed among these aircraft and continuing into the future are other incredible platforms and systems that push the envelope of creativity and innovation well beyond what the public can even conceive.

The Skunk Works began with the desperate need for a response to a threat, the vision of one man, the commitment of a company and the trust of the government. The Skunk Works spirit lives today in the hearts and minds of the men and women who sacrifice daily to ensure that its products meet customer requirements at their defining moments, now and in the future.

I was so blessed to be a “Skunk” for 33 years. I had the honor of meeting “Kelly” Johnson and working for Ben Rich and the lesser-known giants of Skunk Works leadership. I was privileged to work with, and be challenged by, those that created some of the legendary aircraft. I clearly remember my time in the “icebox” waiting for program access, being led into small conference rooms for program indoctrinations, the tight security rules, and working with the incredibly talented and dedicated “Skunks”, subcontractor teams and our customers. I still feel the tension of the boss handing us a set of design requirements that seemed impossible, and then the sense of elation as we met challenge after challenge to exceed expectations. There are countless moments etched into my memory. Walking the grounds outside the wind tunnel where Kelly constructed the project area for the XP-80 – the hallowed grounds of the original Skunk Works. The sense of power I experienced standing next to the wingtip of a SR-71 in full afterburner. The awe of entering Building 309/310 and seeing the F-117A for the first time – and the amusement I enjoyed as I thought of those driving by on Hollywood Way, clueless to the fact that they were only a few hundred feet from the assembly line of one of the most advanced aircraft in the world.

I also remember the sacrifices made by my family who had no clue as to what I did at work, who suffered days and weeks of my absence with no explanation, and countless other inconveniences and frustrations. I am forever indebted to them for their patience and for keeping life moving forward.

And I will forever treasure being a member of the team delivering on the Skunk Works' mission of providing our nation's leadership and warfighters with the tools for decision-making and, if necessary, action to ensure peace, stability and prosperity for the United States.

As you immerse yourself in this wonderful book, know that it was assembled by a man on a mission. I first met Jim in 1981. He was then, and continues to be, the most passionate follower of the Skunk Works I have ever met. He has unmatched resourcefulness in tracking down priceless photos that document the organization's incredible leaps in aircraft technology. This book is testimony to his personal desire to share with the world the amazing machines created by Lockheed Martin's Skunk Works.

Steve Justice
Former Director Advanced Systems Development, Lockheed Martin Skunk Works (retired)

LOCKHEED MARTIN

XP-80 SHOOTING STAR

1944

PROGRAM: XP-80

Name: Shooting Star

Mission: Fighter – interceptor

Length: 34ft 5in (10.49m)

Wing Span: 38ft 9in (11.81m)

Height: 11ft 3in (3.43m)

Max T.O. Weight: 12,650lb (5,738kg)

First Flight: 8 January 1944

Last Flight: 1974 (Chilean Air Force); T-33: March 2017 (Bolivian Air Force)

Crew: 1

Number Built: 6,557 (1,715 P-80s were built, with the remaining production figure being a mix of T-33s and TV-2 and T2V/T-1 SeaStars)

Power Plant: 1 x Allison J33-A-35

Design Speed: Mach 0.54 (410mph; 660km/h)

Service Ceiling: 45,000ft (14,000m)

Combat Radius: 1,200 miles (1,043nm; 1,930km)

Weapons Load: 6 x M3 machine guns; 8 x 5in (127mm) HVAR rockets; 2 x 1,000lb (453kg) GP bombs

In May 1943 the US Army Air Forces (USAAF) called for a jet-powered high-altitude interceptor centered on a capable power plant. One can only imagine Lockheed Chief Engineer Clarence "Kelly" Johnson licking his lips at the prospect of such a challenge. The designation of "Project MX-409" was assigned and the government contract came on 17 June 1943 for development of the XP-80.

During the summer of 1943, Johnson enlisted an elite team of engineers and shop mechanics to gather in a rented circus tent he had pitched downwind from a noxious plastics factory at the edge of Lockheed's facility at Burbank, California. The purpose was to keep nosy onlookers at bay. All he was allowed to tell his team, on orders from the Army Air Force, was that they would be expected to toil ten hours a day, six days a week, for the foreseeable future on a new airplane prototype. They were to work under strict secrecy, completely under his command, according to deadlines most would find impossible to meet.

The group accepted the terms without hesitation, even though few knew the whole story. Newly developed German jet fighters, with their superior speed and acceleration, showed early signs of dominating the skies over Europe. And the US War Department, hoping to quickly level the playing field, had recruited Johnson to build what would become the United States' first true operational jet fighter, the P-80.

With the pressing need to counter the emerging German threat quickly, the War Department gave Johnson a seemingly insurmountable deadline to design and build the new aircraft: 150 days. Johnson gladly took on the challenge. Now it was up to his new team to deliver. And deliver it did. Over the course of the next six months, the Lockheed team exceeded expectations, delivering the sleek XP-80 prototype in 143 days, seven days ahead of schedule.

Everything changed on 26 July 1944, when a lone British twin-engine, piston-powered de Havilland Mosquito PR IX of No. 544 Squadron, Royal Air Force, on its way to take pictures over Munich, encountered a twin-engine German Messerschmitt Me 262 jet fighter. The Me 262 opened fire on the unsuspecting two-man crew and, perhaps through ingrained training or else pure instinct, the Mosquito banked and dodged to safety, managing to turn tail and run. This was the first meeting ever against a jet-powered foe and the fact that the Germans were able to field such a lethal implement was a new realization for the Allies. Jet power promised speed and greater flight loads that would lead directly to more potent armament options. It seemed that the Germans held the upper hand.

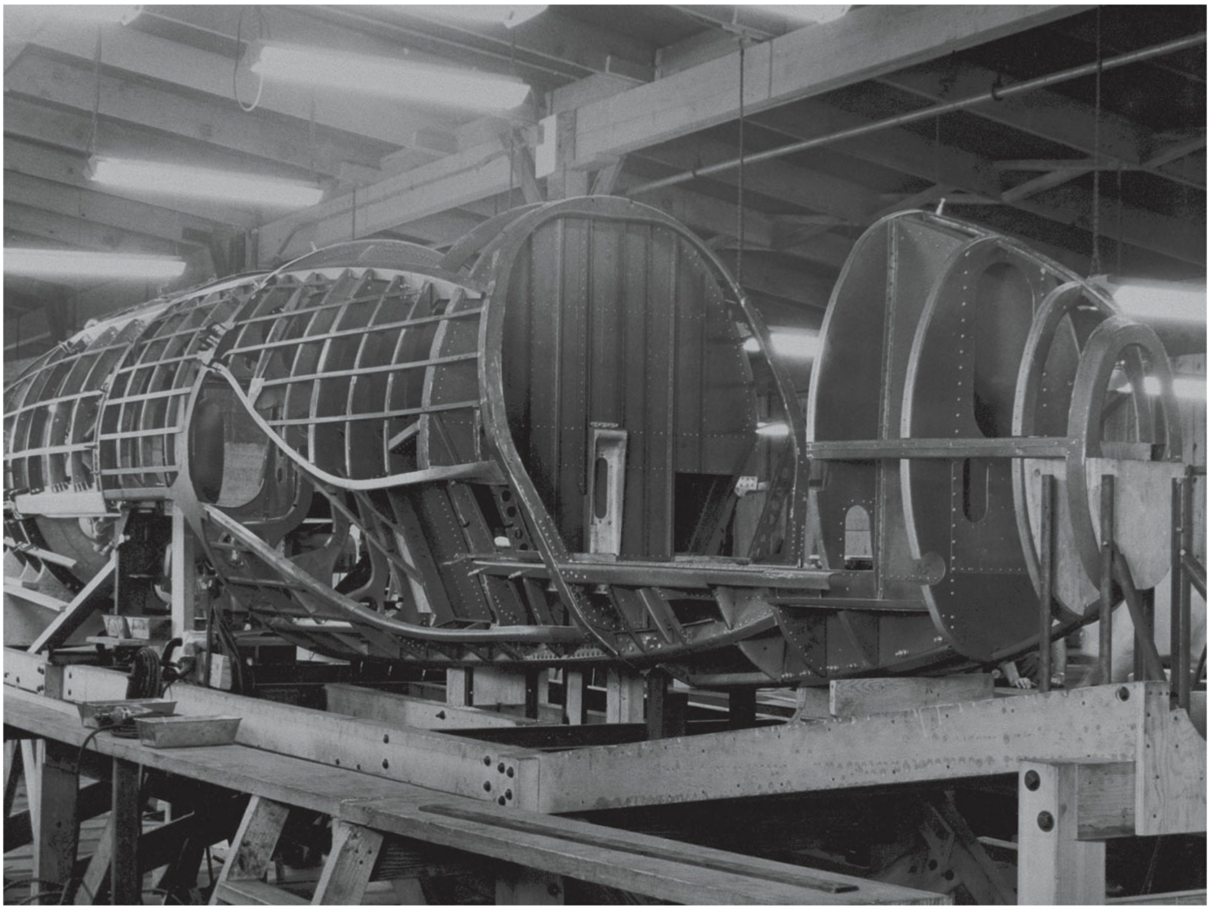
On 8 January 1944, the XP-80 was ready for official display in front of military and contracting officials at Muroc Army Air Field (AAF), California. The XP-80 powered up with a screech from the Goblin turbojet and took flight in a seemingly effortless glide. Its initial acceleration made it slower than its piston-powered counterparts but once it hit stride, the XP-80 really held its own. With on-site repairs, the XP-80 was raised from the earth once more and produced a single-aircraft airshow for all in attendance. The future of jet-powered flight could now be realized more than ever before as the XP-80 became the first American aircraft to surpass and consistently maintain the 500 mph mark. It was dubbed the Shooting Star in honor of its unparalleled speed, with some modified models capable of passing 600mph. With its bullet-shaped fuselage, flush rivets and smooth skin, the production P-80 was not only a looker but also an intimidating attack plane, boasting six .50-caliber machine guns and underwing shackles for bombs, a deadly mix of strength and speed. Although the P-80 did not see action in World War II, the timely delivery of the Shooting Star by Lockheed set the stage for its early dominance during the Korean War as America's front-line fighter, becoming one of the most successful first-generation jet-powered fighters, as well as providing the airframe for two very important derivatives, the two-seat trainer T-33 and the F-94 Starfire all-weather interceptor.

Some 75 percent of enemy losses during the initial months of the Korean campaign were due to air attacks by Shooting Stars. By 1950, a P-80 under the control of Lt Russell Brown shot down a North Korean MiG-15 in the world's first jet-versus-jet air battle.

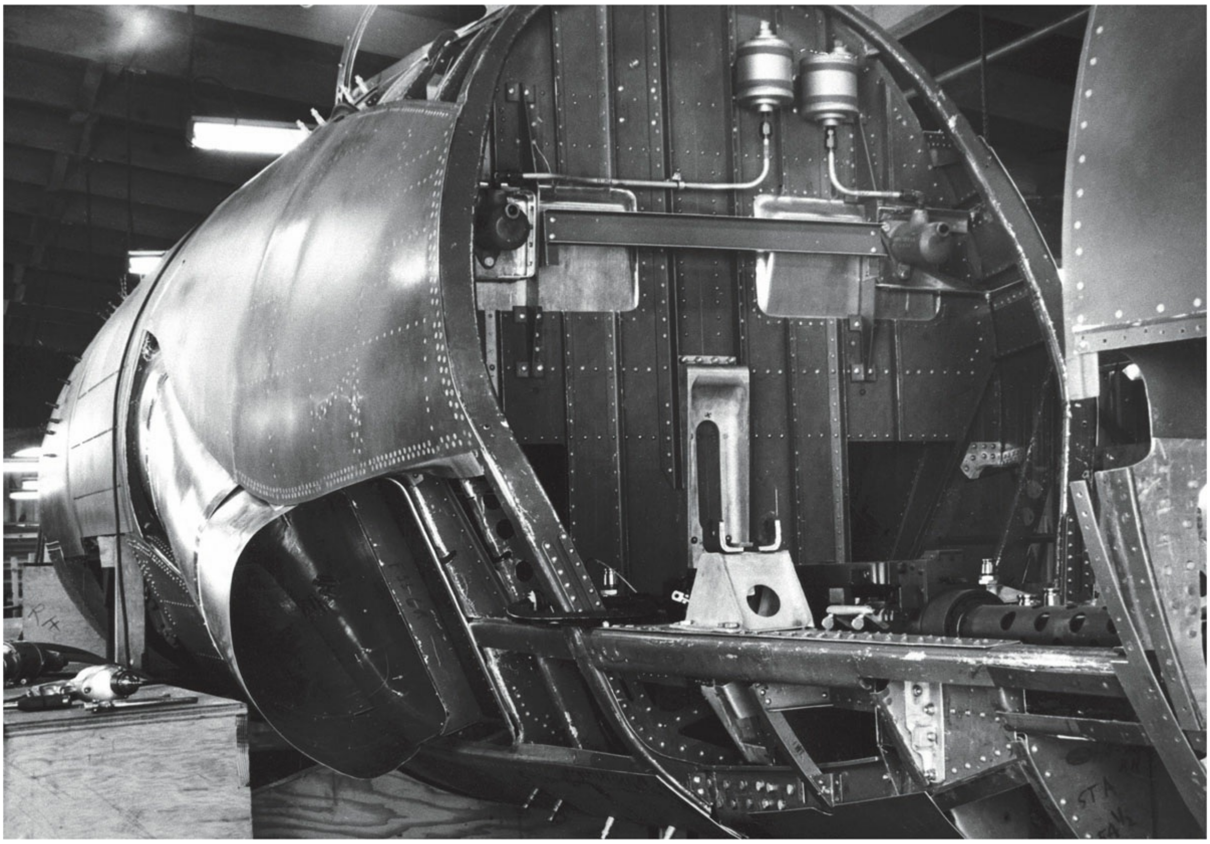
An iconic photo of the Skunk Works founder and master design engineer with a model of the XP-80, the airplane that gave birth to what is now called the Skunk Works. (Lockheed Martin)

“Lulu Belle,” the prototype XP-80, at the Smithsonian Air and Space restoration center at Silver Hill, MD. (SASM)

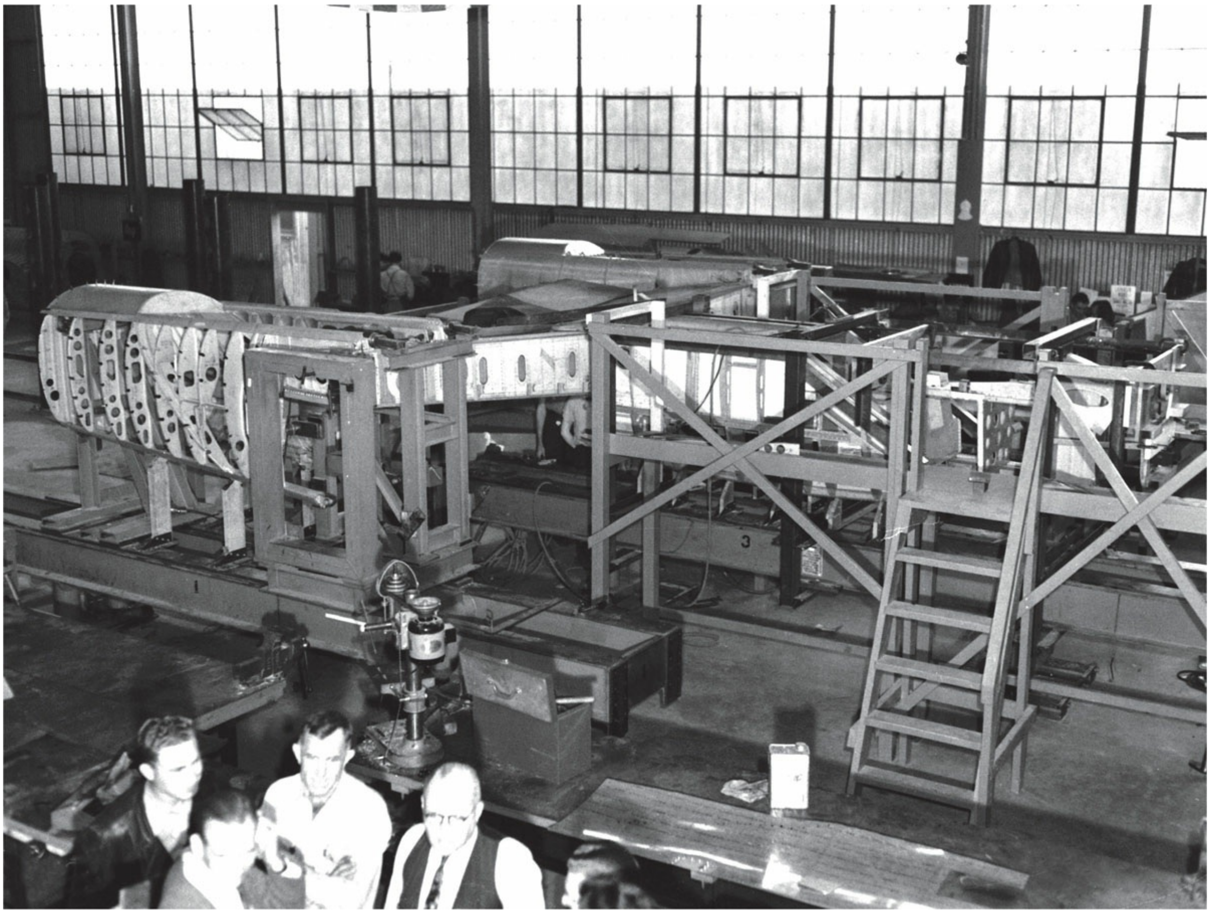
Kelly Johnson shakes hands with test pilot Tony LeVier after a successful test flight. (EAFB/HO)



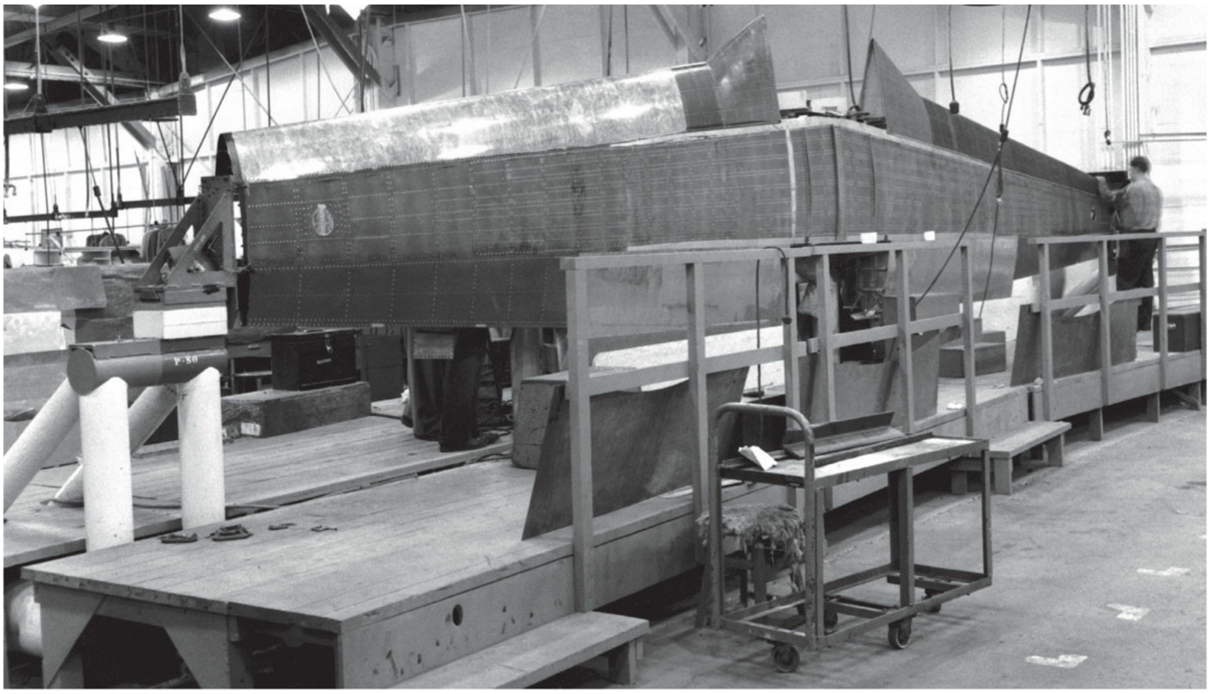
Buildup of the very first XP-80 at the Burbank production facility. (EAFB/HO)



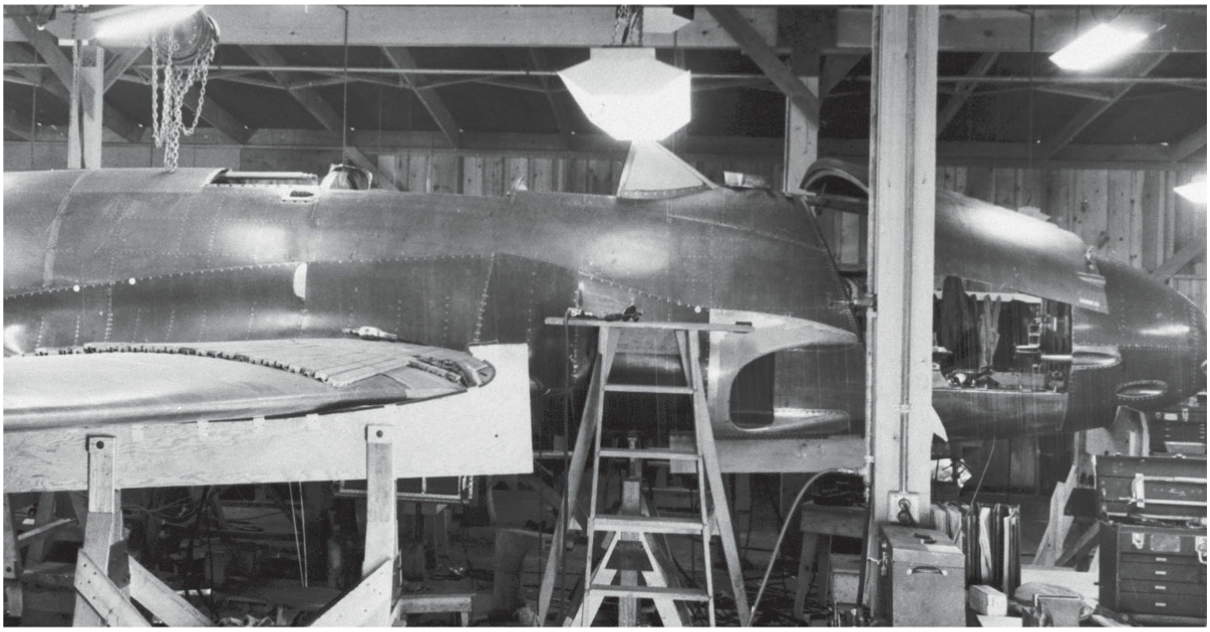
A few weeks later, the production team has skinned the fuselage of the XP-80. (EAFB/HO)



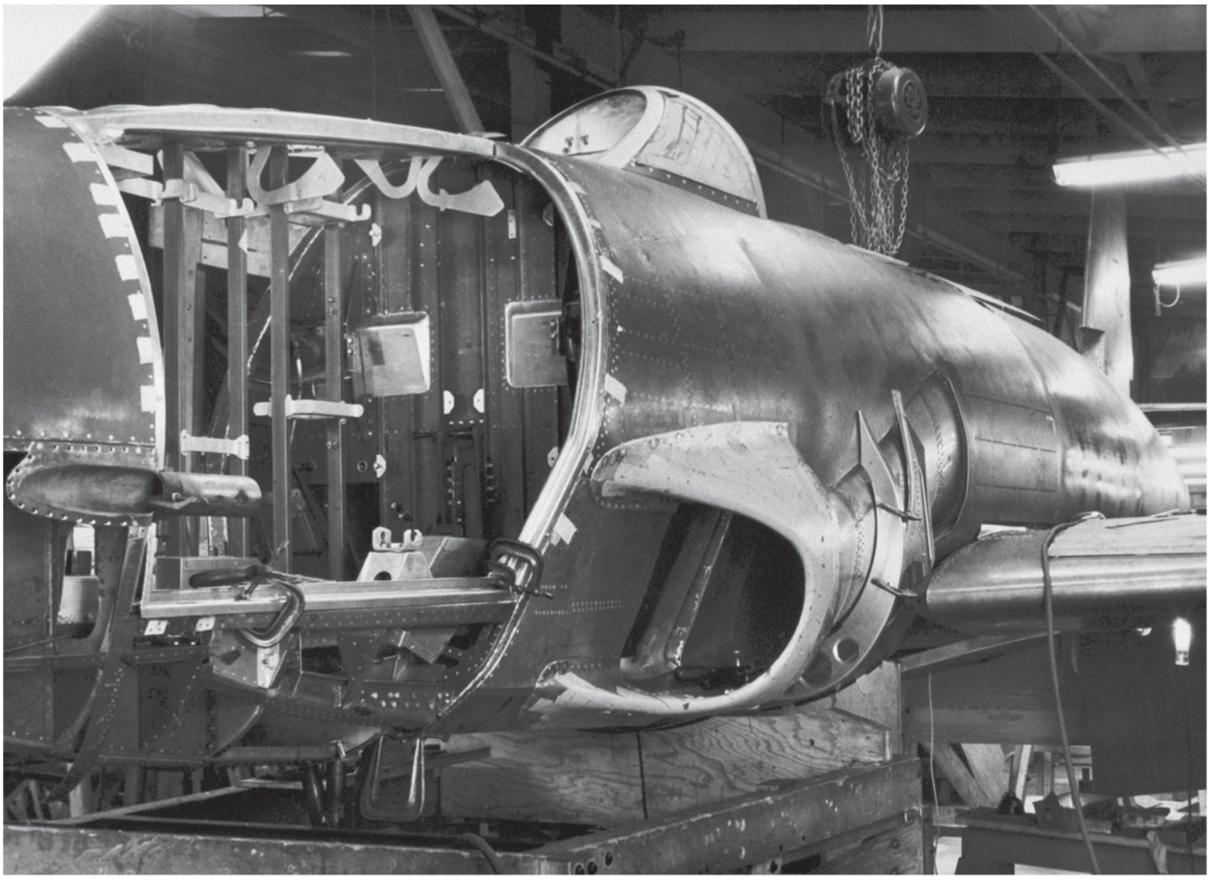
Buildup of the XP-80's wing using soft tooling made of wood versus the traditional metal structure. (EAFB/HO)



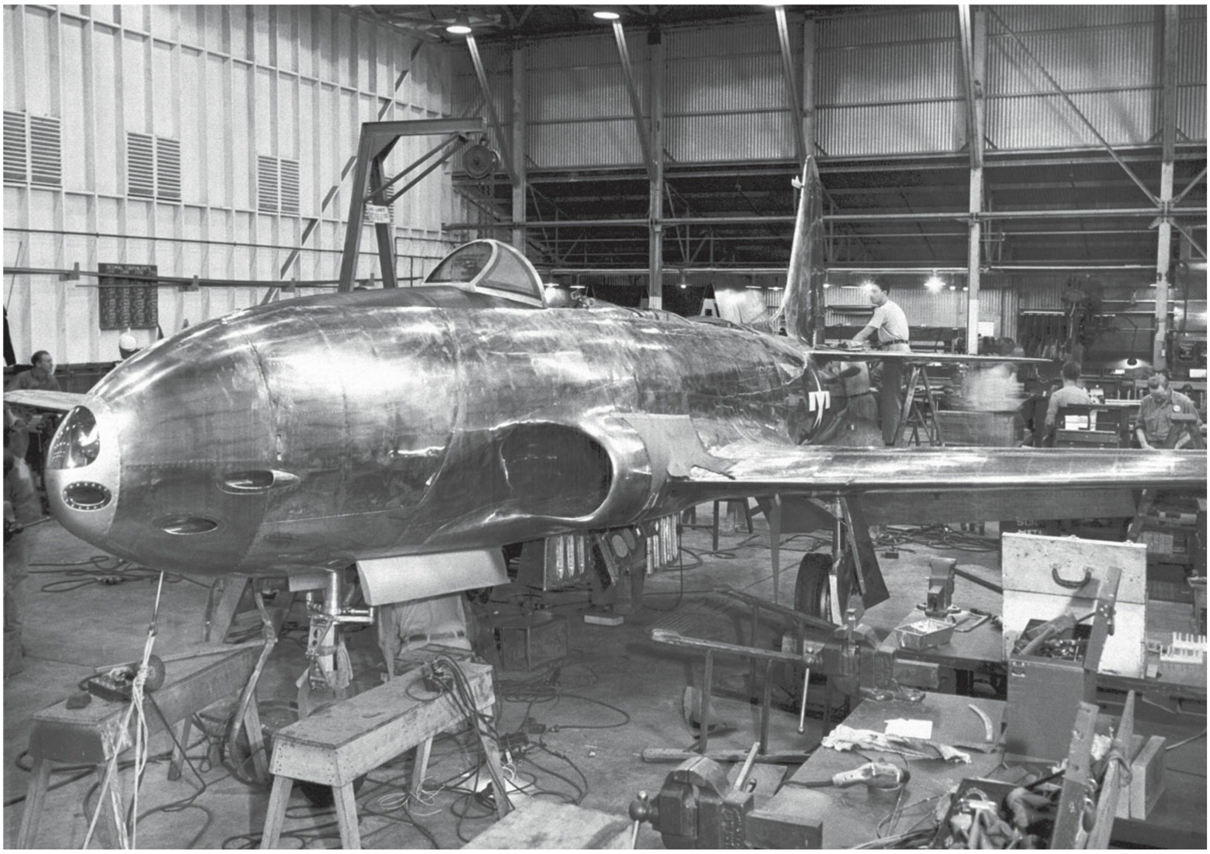
An almost completed wing for the XP-80 in the buildup fixture allowing for easier work on both sides of the wing during the riveting process. (EAFB/HO)



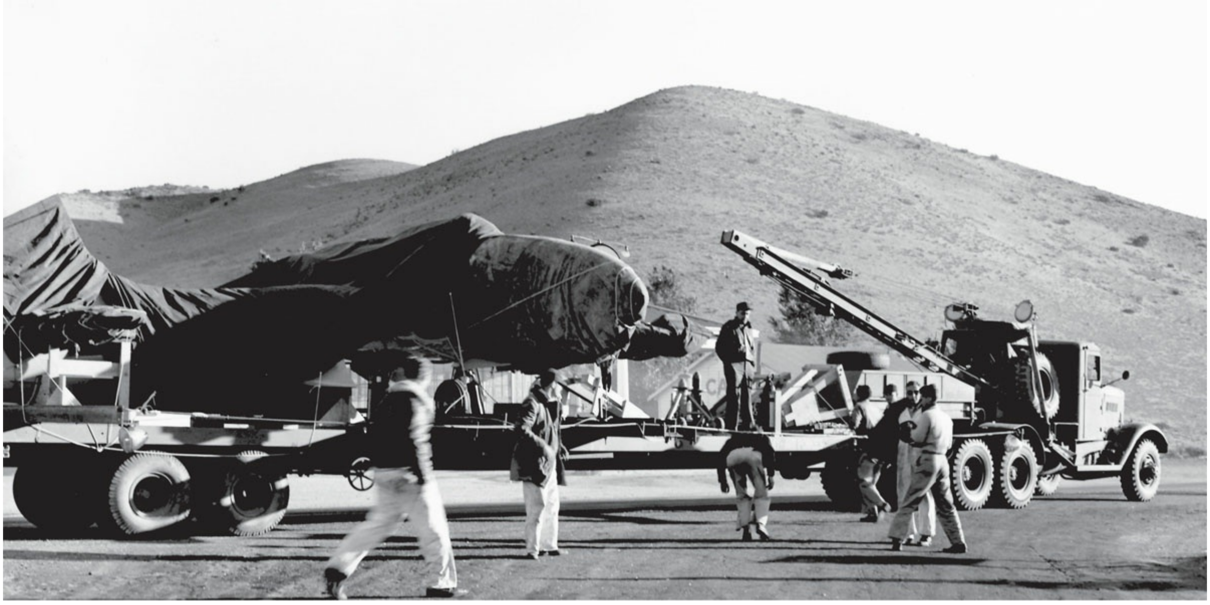
With the wing attached, the XP-80 is waiting for the installation of internal components. (EAFB/HO)



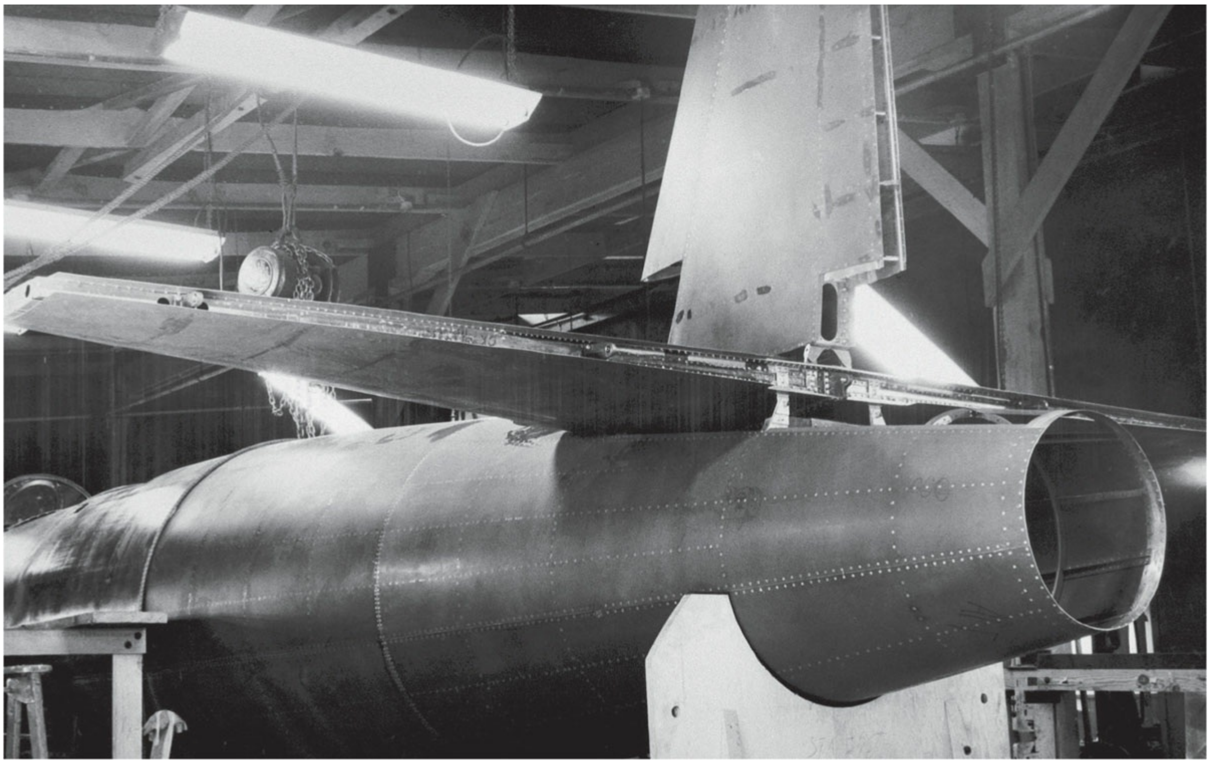
The newly assembled XP-80 is stuffed into the Burbank production facility as crews put the finishing touches prior to its move to Muroc AAF. (EAFB/HO)



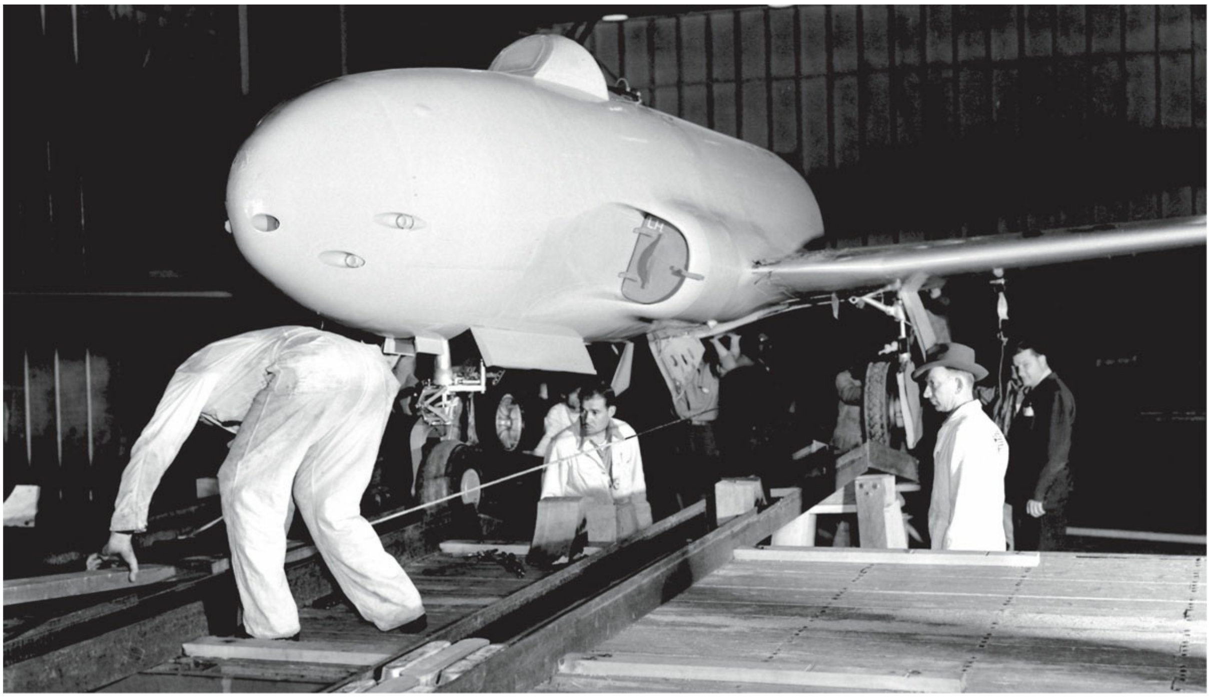
The almost completed XP-80 is nearly ready for paint and transportation to the then Muroc AAF, later renamed after Edwards Air Force Base (AFB). (EAFB/HO)



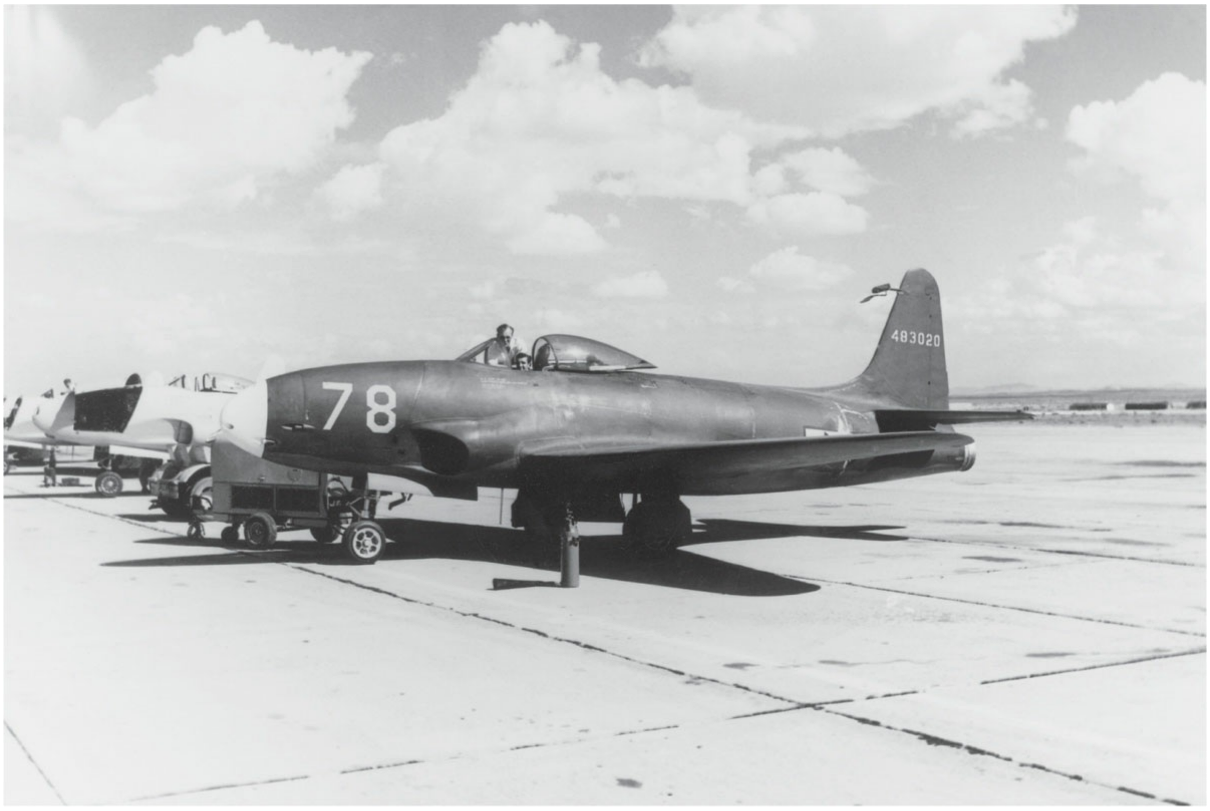
On the way to Muroc AAF via what is now the California State Highway 14. (EAFB/HO)



Buildup of the after fuselage just attached to the forward fuselage during construction of the XP-80. (Lockheed Martin)

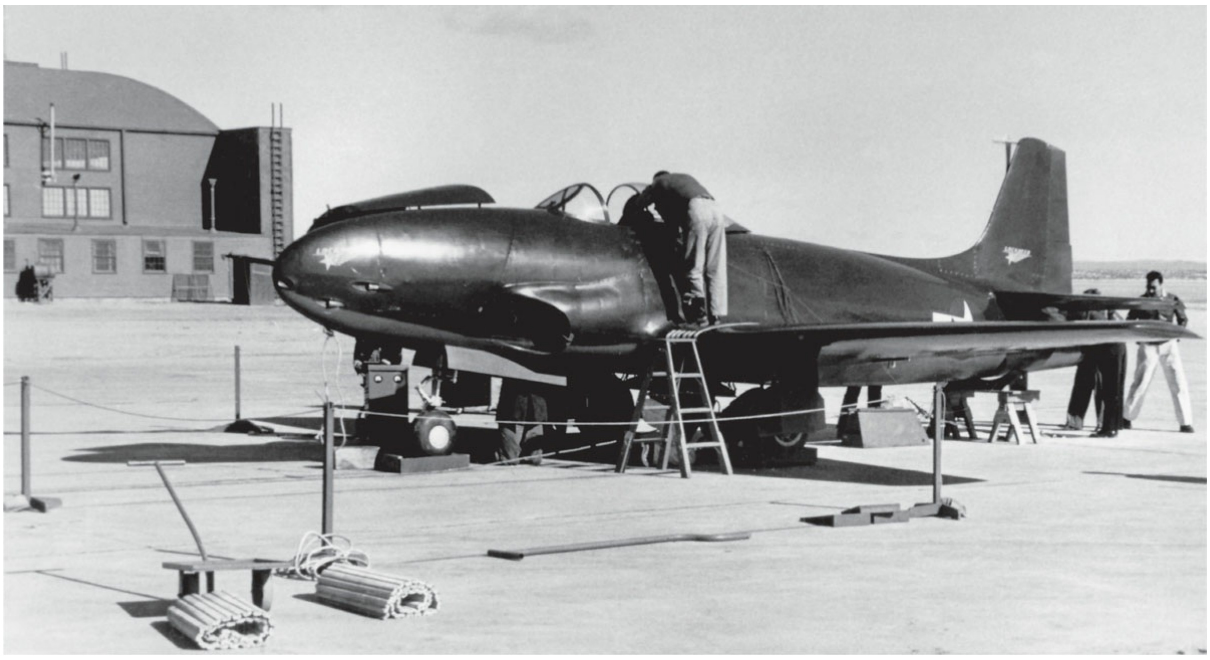


A unique way to move the XP-80 from Burbank to Muroc AAF was to take off the aft fuselage, remove the engine and slide the XP-80 sideways on the flatbed truck; but it was still a wide load. (EAFB/HO)

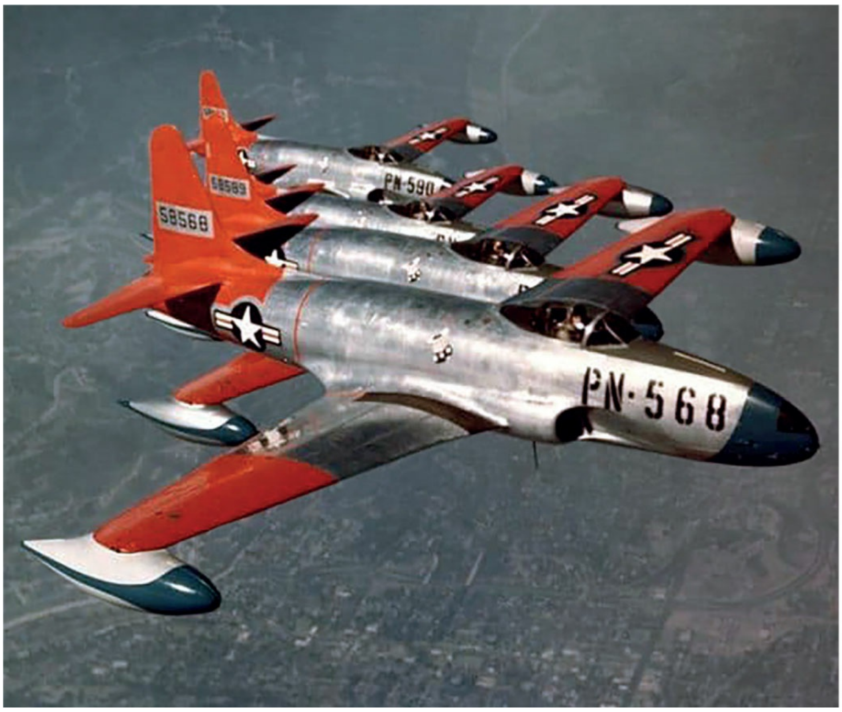


The XP-80 on the flight line at Muroc AAF in late 1944. (EAFB/HO)

"Lulu Belle" on Rogers Dry Lake prior to its first flight. (EAFB/HO)



The XP-80 undergoing static engine runs at Muroc on 5 January 1944, three days before its first flight. Installed thrust was measured using a simple but accurate scale attached to the XP-80 via a pulley and cable system. (EAFB/HO)

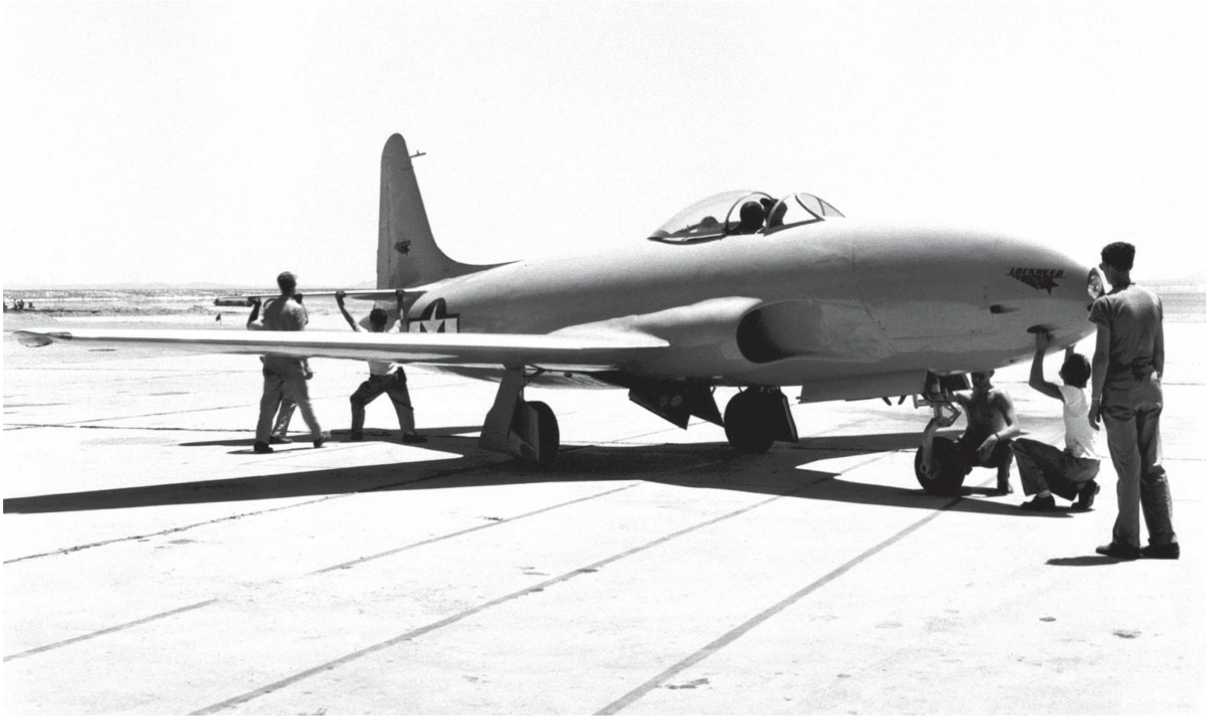


These four F-80s were assigned to the 94th Fighter Squadron and were part of 31 specially modified P-80s that featured canopy defrosting for service in Alaska.

(NASM)

U.S. AIR FORCE
91826
FT-826
FT-555
FT-522

On 8 November 1950, a flight of four straight-winged jets from the 8th Fighter-Bomber Squadron swooped down on an airfield at Sinuiju, North Korea – on the Korean side of the border with China. (Author's collection)



The XP-80 fully assembled and ready for testing on the ramp of Muroc AAF in late 1947. (EAFB/HO)

U.S. AIR FORCE
0-1412

The NT-33A was an in-flight simulator operated for decades in support of numerous Department of Defense (DoD) projects. The NT-33A was used to study flying qualities, cockpit displays, control sticks and flight control designs of many, widely varied aircraft. (NMUSAF)

U.S. AIR FORCE
15358

The subsequent F-94B, which entered service in January 1951, was outwardly virtually identical to the F-94A. The Allison J33 turbojet had a number of modifications made, though, which made it a very reliable engine. (Author's collection)

U.S. AIR FORCE
FA-054
U.S. AIR FORCE
01054

The F-94C series of all-weather interceptors was developed from the Lockheed P-80 Shooting Star. The prototype F-94 first flew on 1 July 1949. (NMUSAF)

LOCKHEED MARTIN

XF-90 PENETRATION FIGHTER

1949

PROGRAM: XF-90

Name: Starfire

Mission: Long range penetration fighter – prototype

Length: 56ft 2in (17.12m)

Wing Span: 40ft (12.2m)

Height: 15ft 9in (4.8m)

Max T.O. Weight: 31,060lb (14,090kg)

First Flight: 3 June 1949

Last Flight: 15 August 1950

Crew: 1

Number Built: 2

Power Plant: 2 x Westinghouse J34-WE-15 turbojets

Design Speed: Mach 0.87 (665mph; 1,070km/h)

Service Ceiling: 39,000ft (11,890m)

Combat Radius: 2,300 miles (1,999nm; 3,701.5km)

Weapons Load: 6 x 20mm cannons; 8 x 5in (127mm) HVAR rockets; 2,000lb (907kg) bombs

One of the hottest-looking fighters ever to be built but not to go into production was the Lockheed XF-90. It was the first US-built, swept-wing jet to be equipped with afterburners and wingtip fuel tanks as standard equipment and have fully adjustable vertical and horizontal stabilizers. Fowler flaps and leading-edge slats improved airflow over the wings, making the F-90 one of the pioneers in 35-degree swept-wing technology. In tests, the XF-90 exceeded Mach 1 15 times.

After World War II, the USAAF needed a "penetration fighter," capable of escorting bombers to and from their targets. In 1945, the USAAF issued a request for a fighter with a combat radius of about 900 miles. Competitors for the contract included McDonnell's XP-88A, North American's XP-86C and Lockheed's XP-90. Lockheed received a contract for two prototype XP-90s on 20 June 1946.

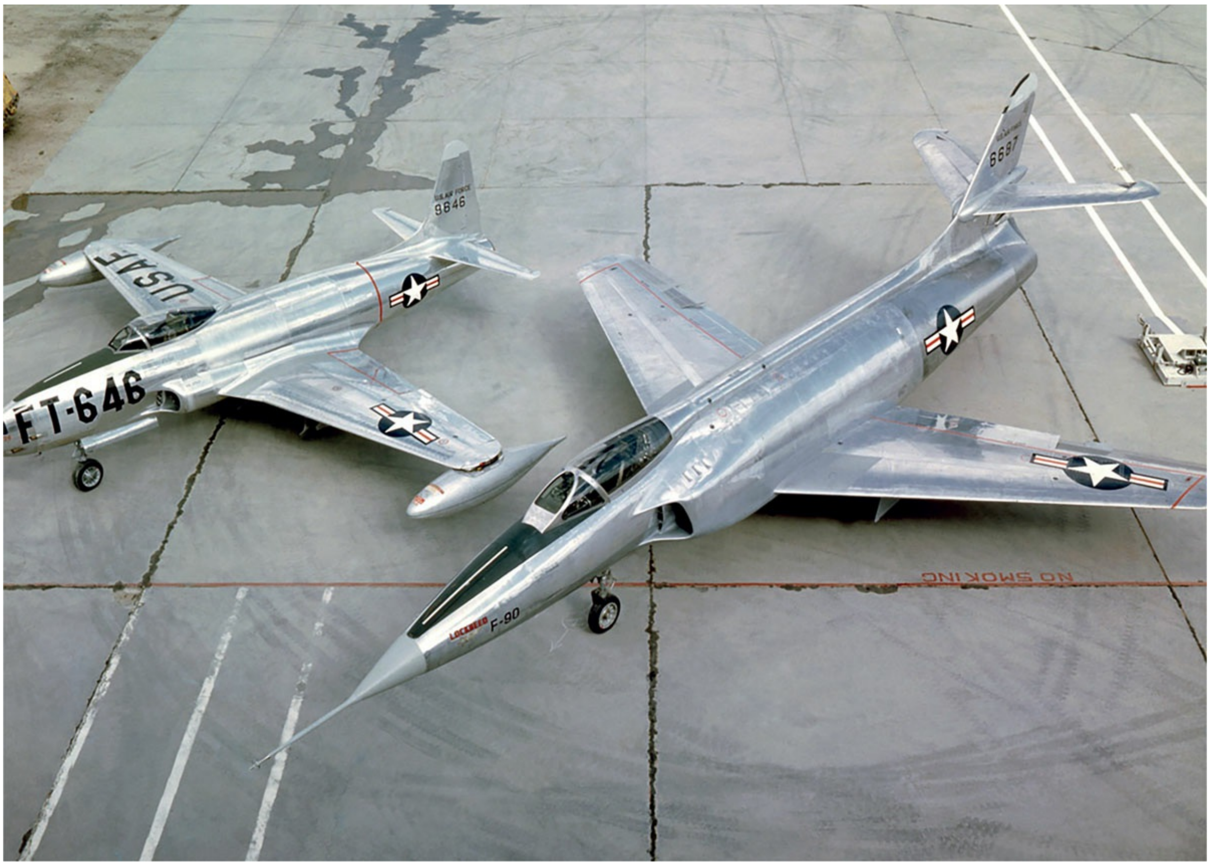
Although Chuck Yeager had broken the sound barrier on 14 October 1947, it was too late to be of any help with the design of the XF-90. The first prototype was tested to destruction at the National Advisory Committee for Aeronautics Laboratory in Cleveland, Ohio, and became scrap. The second prototype was sent to the Nevada Proving Ground for use in a nuclear weapons test and was subjected to three nuclear blasts. The explosions severed the tail and blew the landing gear from the wing; the main wing structure was buckled and scorched.

Despite its sleek appearance, the XF-90 was pretty much of a dog when it came to performance. The reason was that it was overbuilt and underpowered. The plane was expected to exceed the sound barrier, but very little was known at the time as to what would happen. The aluminum skin was built with a stronger 75ST aluminum rather than the standard 24ST aluminum alloy, plus a greater thickness to make it four times more stress-resistant than standard construction. Weighing more than a DC-3, it was built to withstand 12g, making it 80 percent heavier than the F-86. Additionally, it was seriously underpowered with its two J34 Westinghouse engines providing a total thrust of only 6,000lb required to push 27,200lb of aircraft.

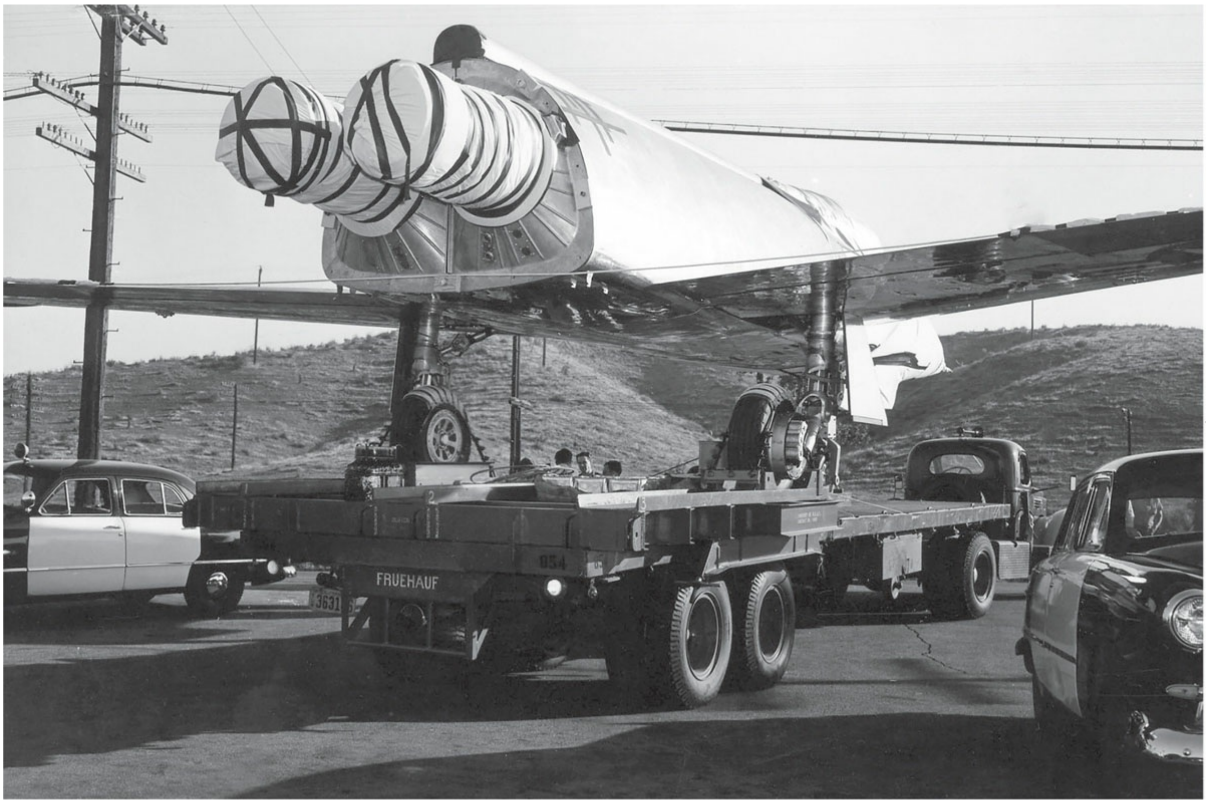
On 17 May 1950, as the test program was conducting power-on dives to work up to the sound barrier, the aircraft made a dive at fairly low altitude and disappeared in the haze. At that same moment, ground observers heard a tremendous boom. They thought the airplane had exploded but to their relief, it had dived to Mach 1.12 and everything was fine. The XF-90 went on to exceed the sound barrier a number of times, and handled fine with no structural problems.

The XF-90 was a precursor to the "missile with a man in it," the F-104 Starfighter. It caught the nation's attention with its sleek-looking design; it also made for splashy advertising for Westinghouse engines and was featured on the 1953 September cover of the comic book Blackhawk. Thereafter, the young baby boomer generation would be mesmerized with the coming of the jet age and each new adventure of the pilot Blackhawk and his buddy Chuck. This was the atomic age, where children lived in fear of nuclear attack and were taught to hide under their desk in schools during air raid rehearsals. With his squadron of six sleek F-90Bs, Blackhawk and his fighters would keep the threat of the Red aggressors at bay.

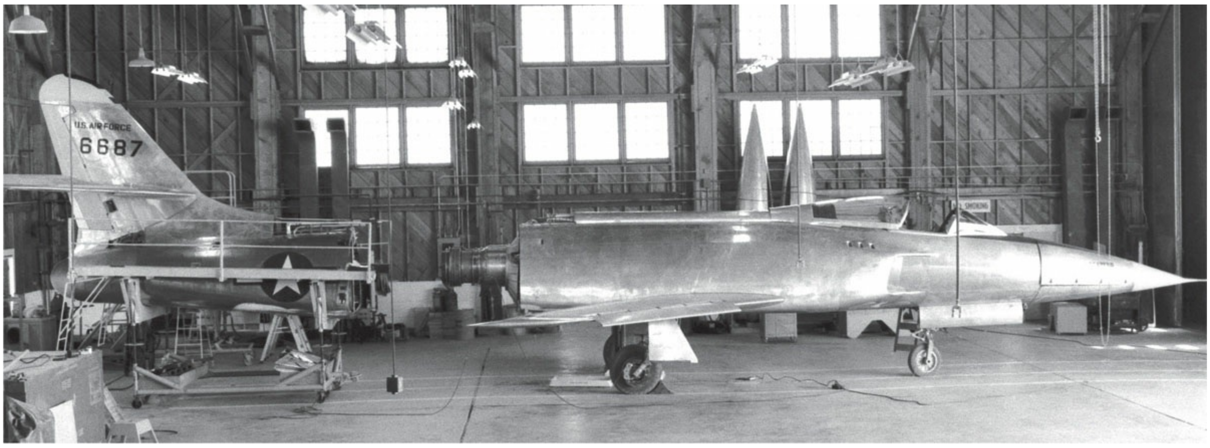
In the late 1980s, the second prototype was recovered and decontaminated for preservation. It will be housed in the National Museum of the United States Air Force, near Dayton, Ohio, where it will be exhibited exactly as it sat, out in the desert for half a century.



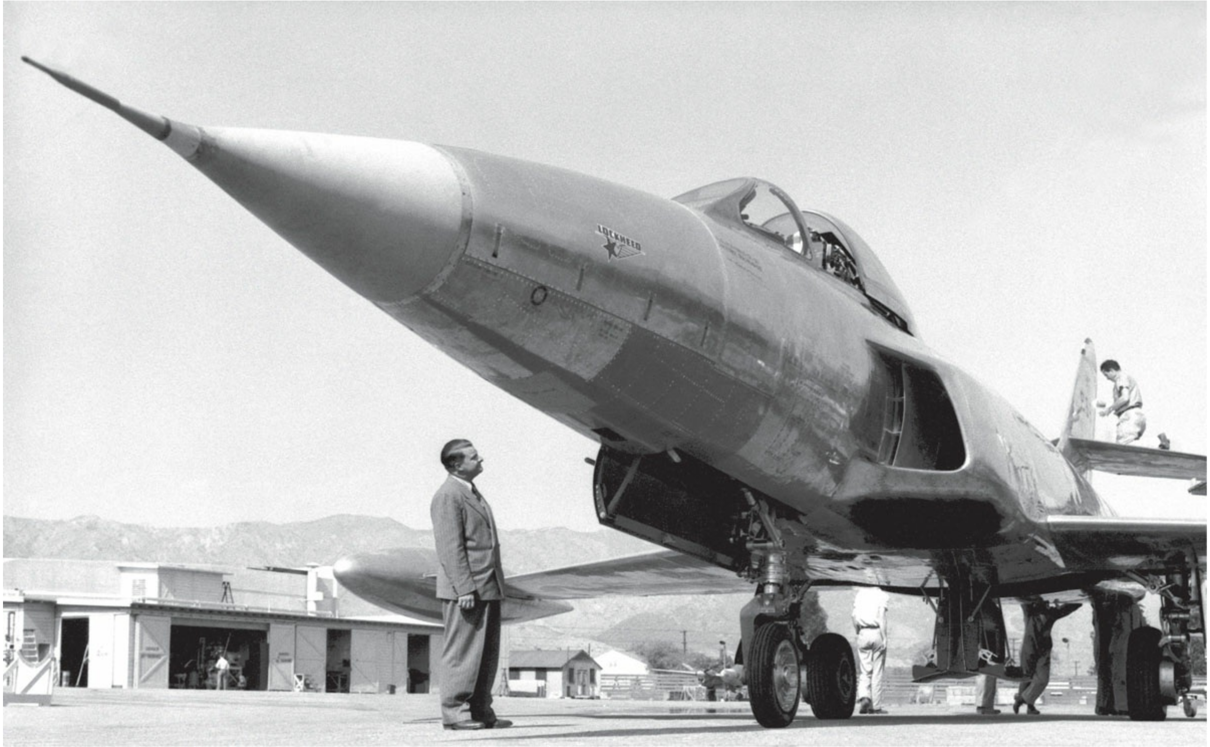
Family photo of the XF-90 with the venerable P-80A on the ramp at Edwards AFB, CA. The XF-90 was approximately twice as heavy as the P-80. (EAFB/HO)


FRUEHAUF
954
3631

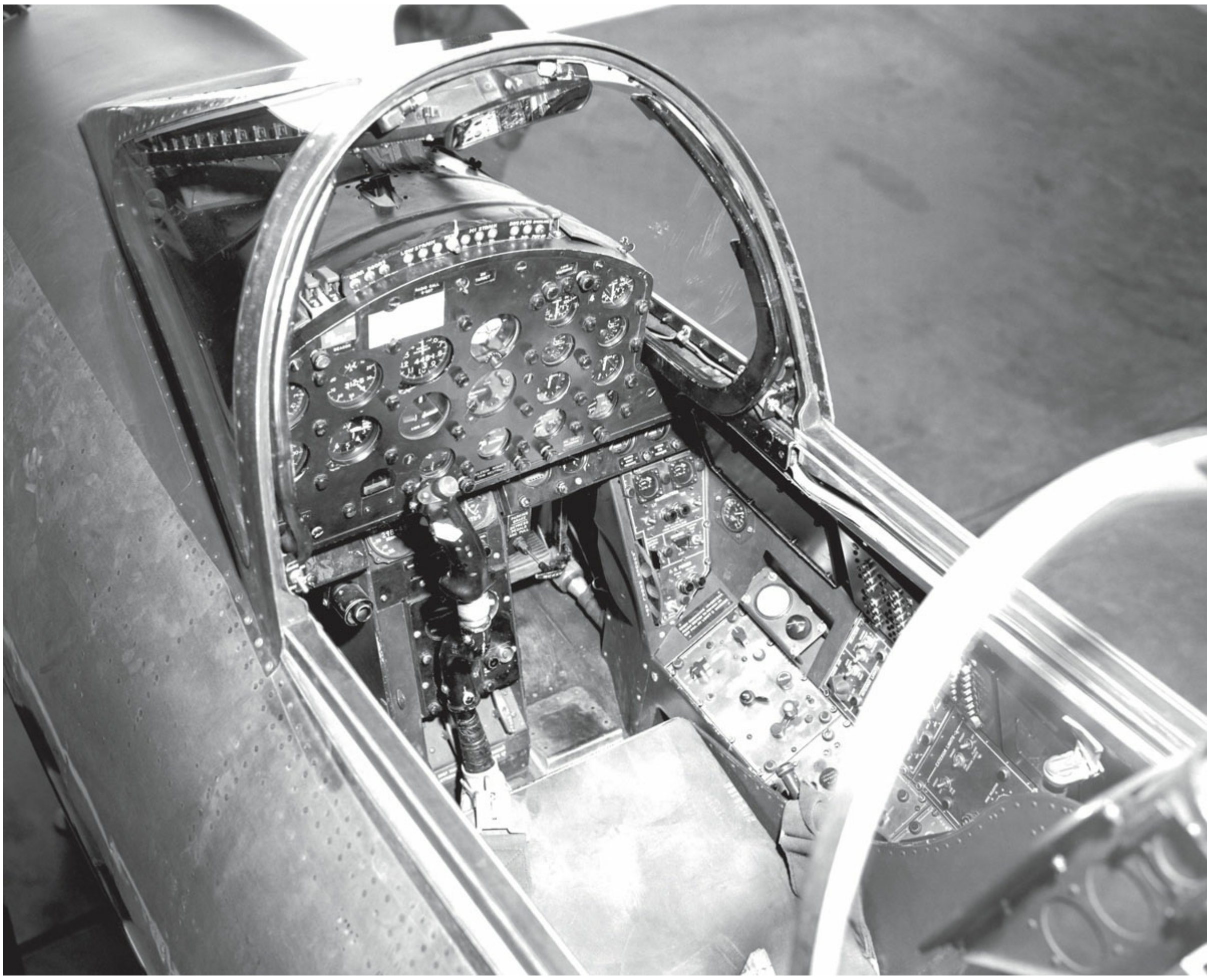
All ready for its trip to Edwards AFB in late May 1946. Like the XP-80, the XF-90 had to be moved by the road. The XP-90 designation was changed to XF-90 shortly after the end of World War II. (EAFB/HO)


U.S. AIR FORCE
6687
SMOKING

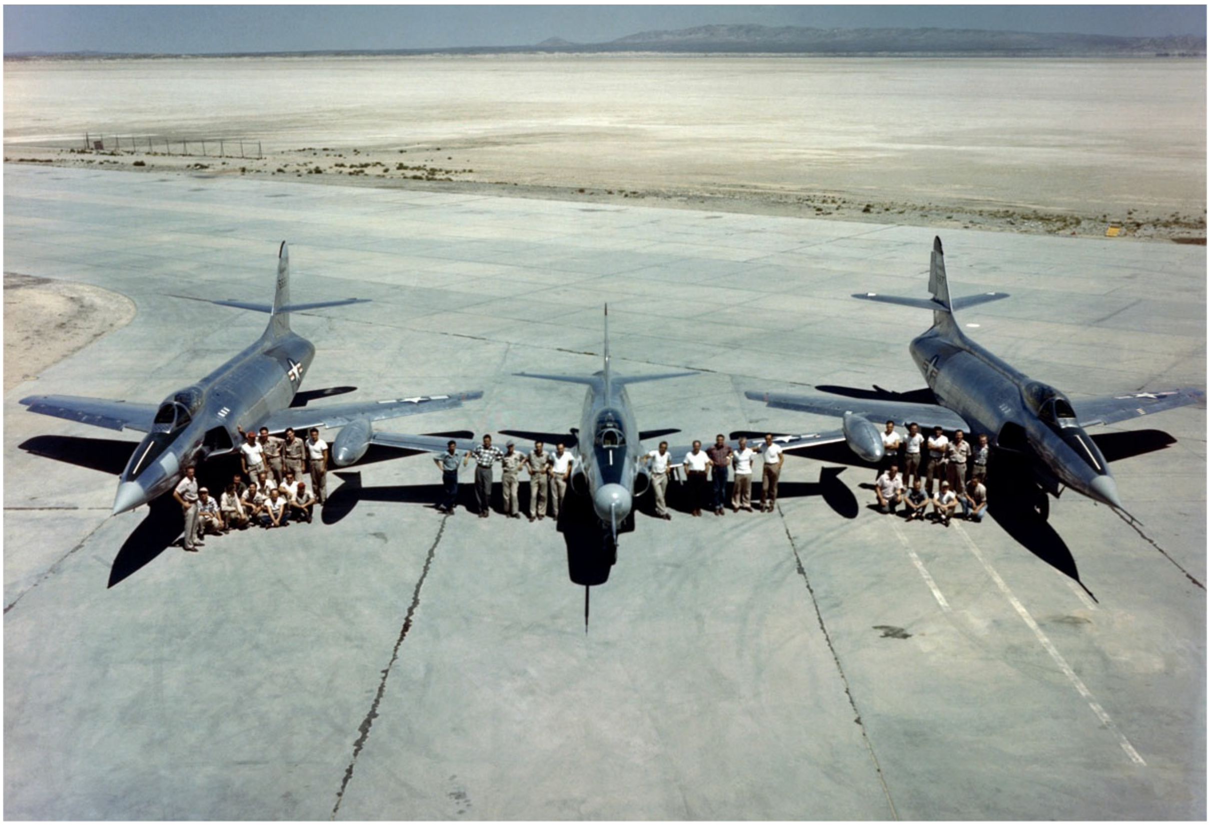
The XF-90's field maintenance was performed as necessary at Edwards AFB in hangars allocated to Lockheed by the Air Force for use during flight-testing of the XP-90. (EAFB/HO)



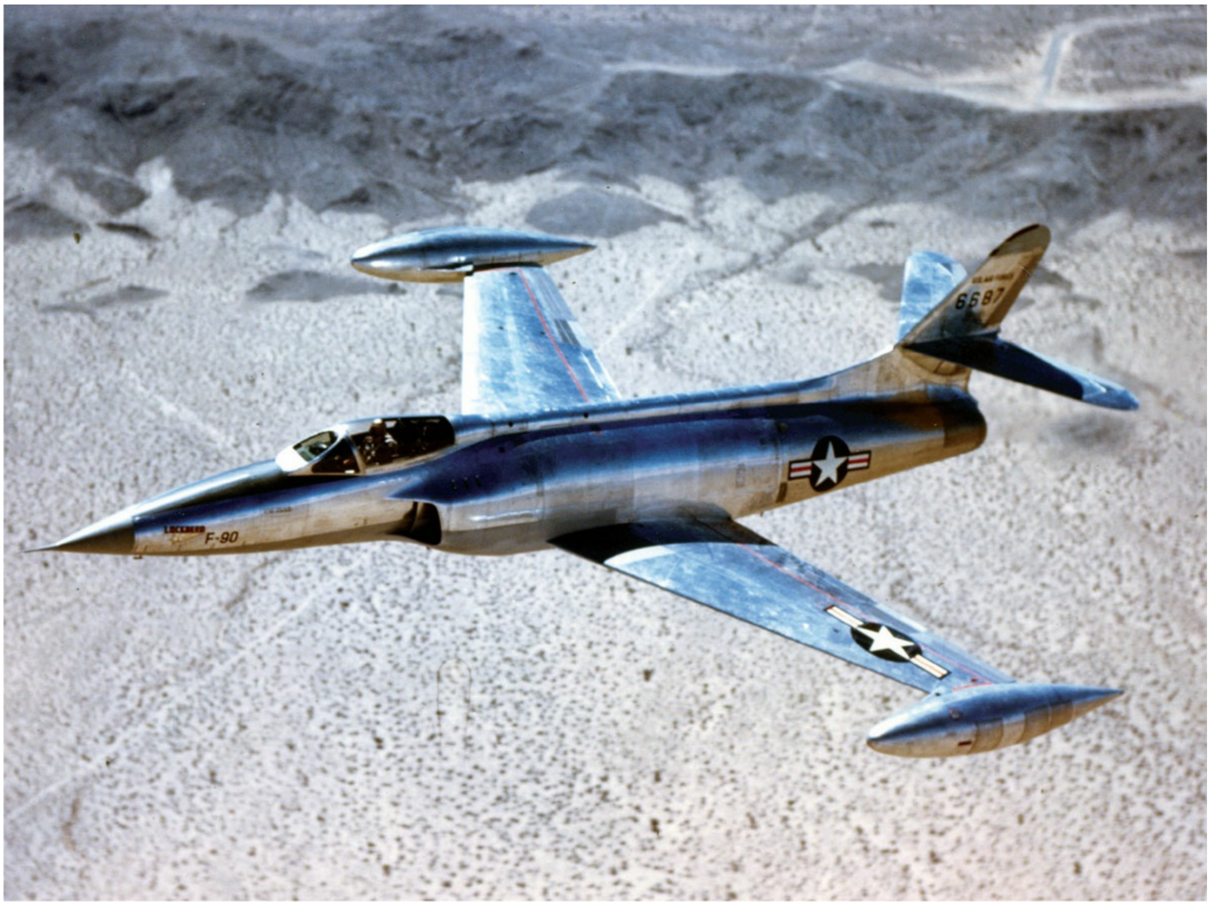
The Head Skunk, Kelly Johnson, looks on as the very first X-90 is prepped for its first taxi test. (EAFB/HO)



The XF-90's cockpit, showing a family resemblance to that of the P-80. (EAFB/HO)



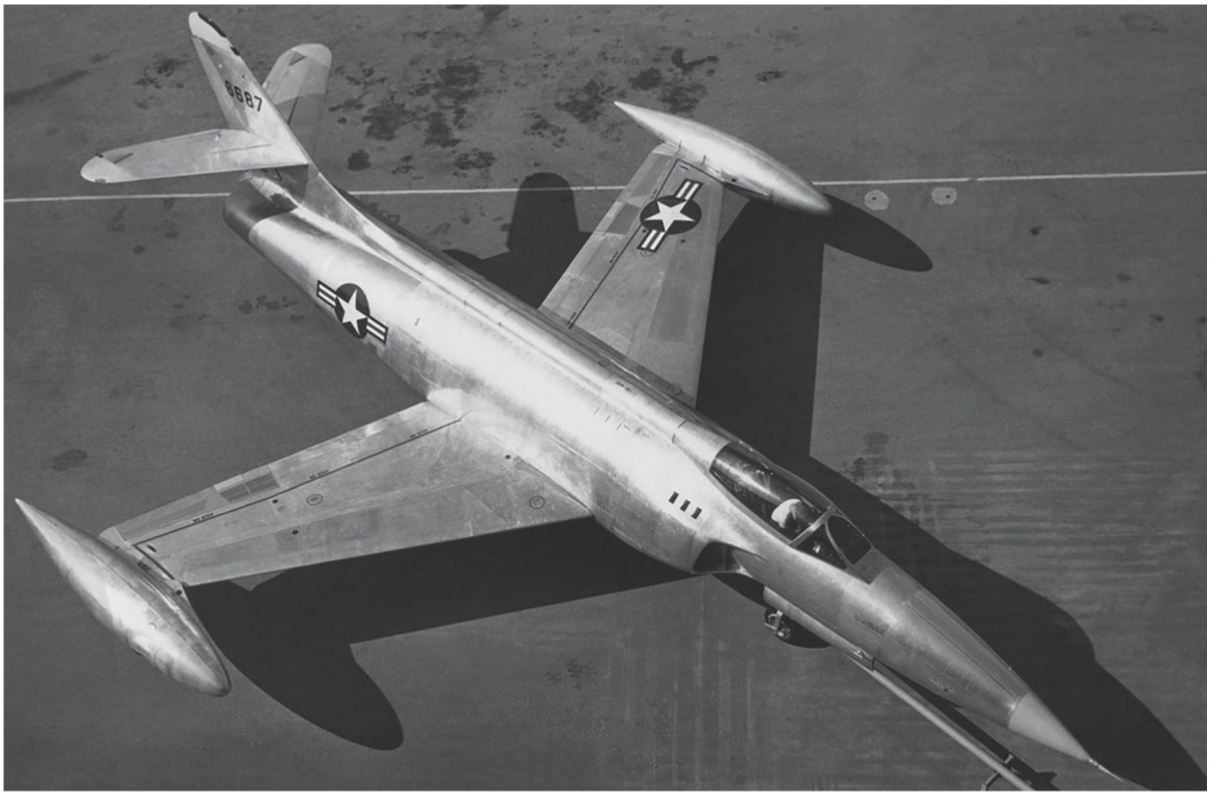
Both XF-90 serial numbers 46-0687, 46-0688 and the prototype YF-94C, serial number 50-0955 on the ramp of Edwards AFB in the early months of 1950. (Lockheed Martin)


6687
LOCKHEED
F-90

The XF-90 flies sporting newly installed wing-tip tanks in 1949. (Lockheed Martin)

A belly view of the XF-90 as it flies high over the Mojave Desert during flight-testing in the late 1940s. (Lockheed Martin)

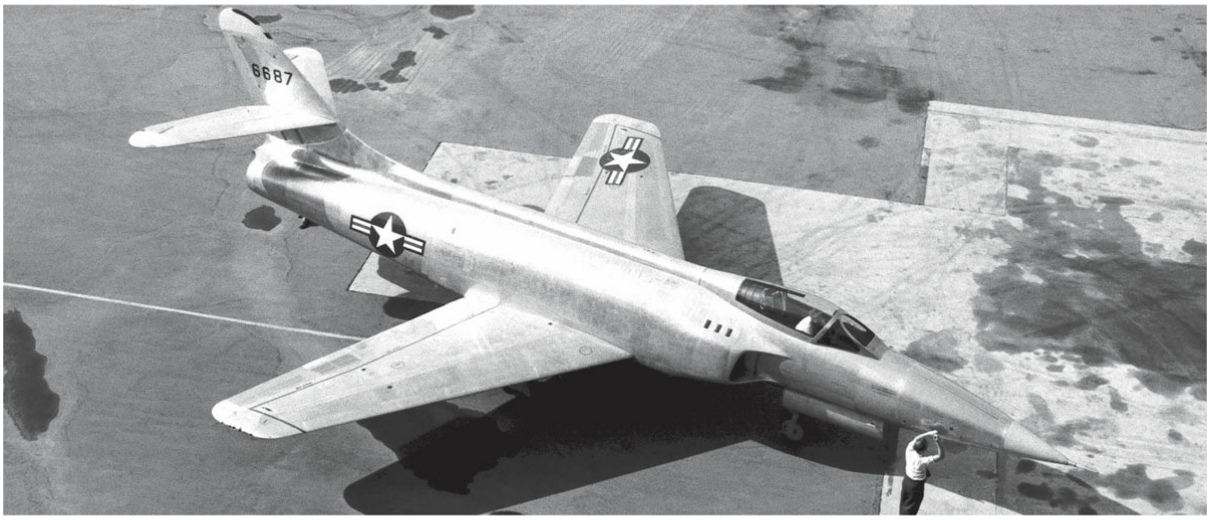
Lockheed senior test pilot Tony LeVier smiles as he flies in formation with the photo chase plane over the Central Valley of California. (EAFB/HO)



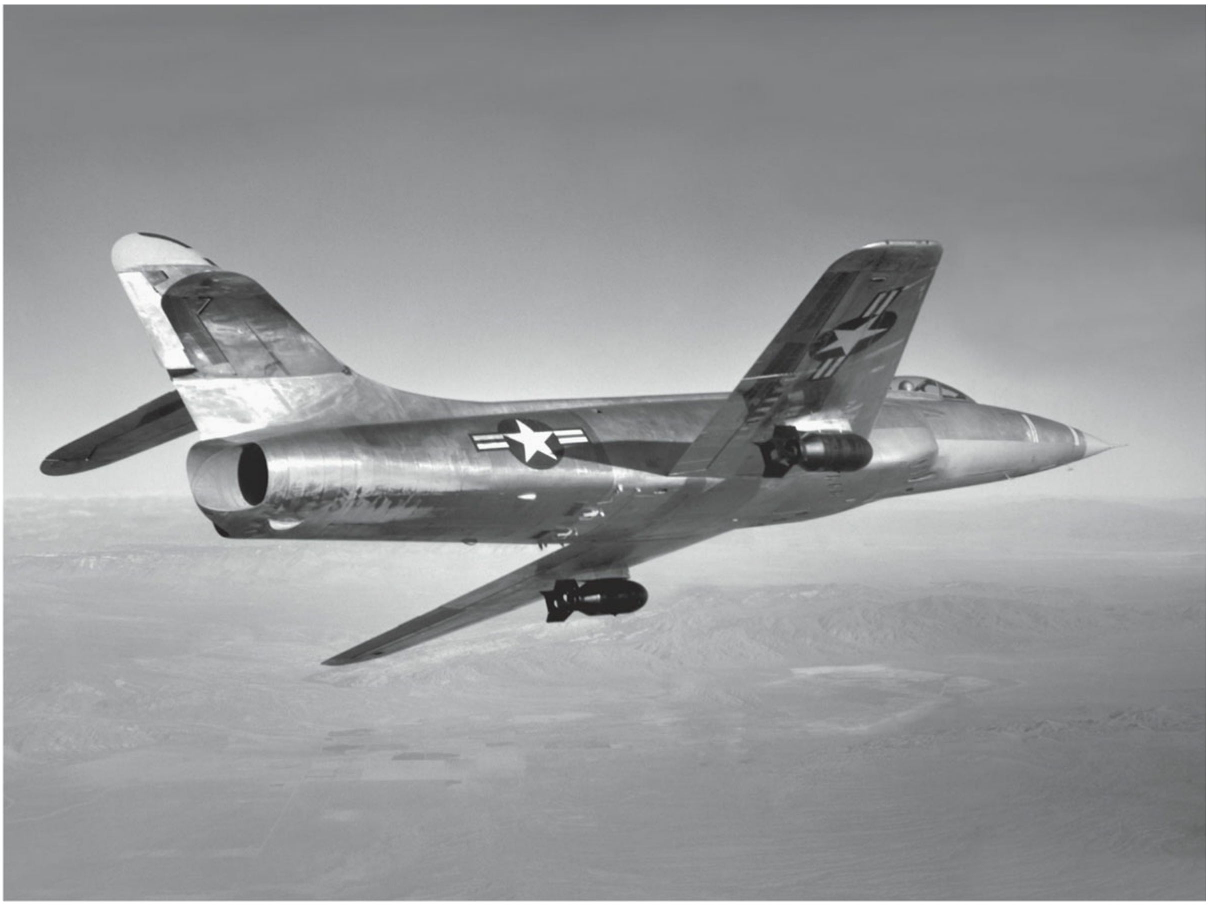
A look-down view of the XF-90 on the ramp at Edwards AFB in 1949. (EAFB/HO)

LOCKHEED
F-90

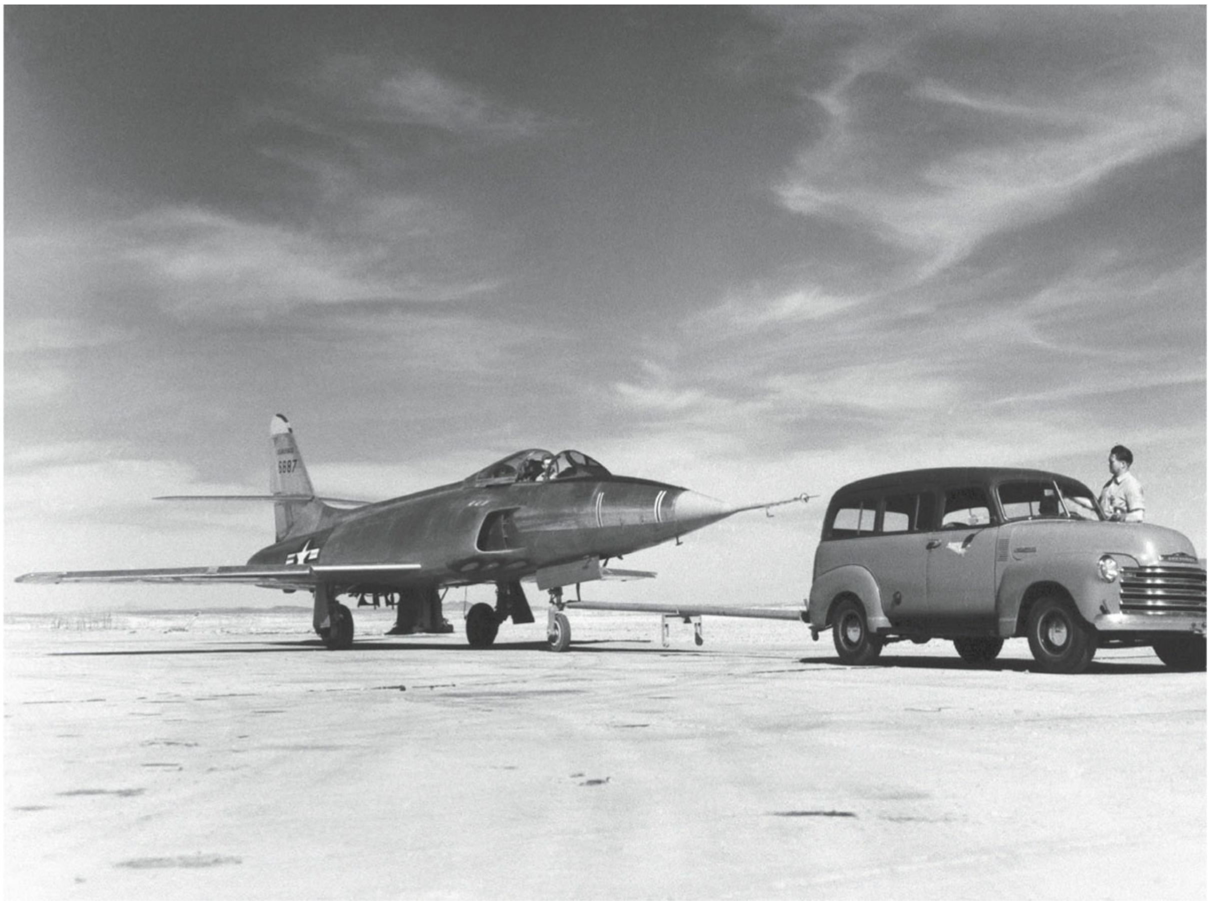
A very happy Tony LeVier is all smiles after the first flight of the XF-90 on 3 June 1946. (Author's collection)



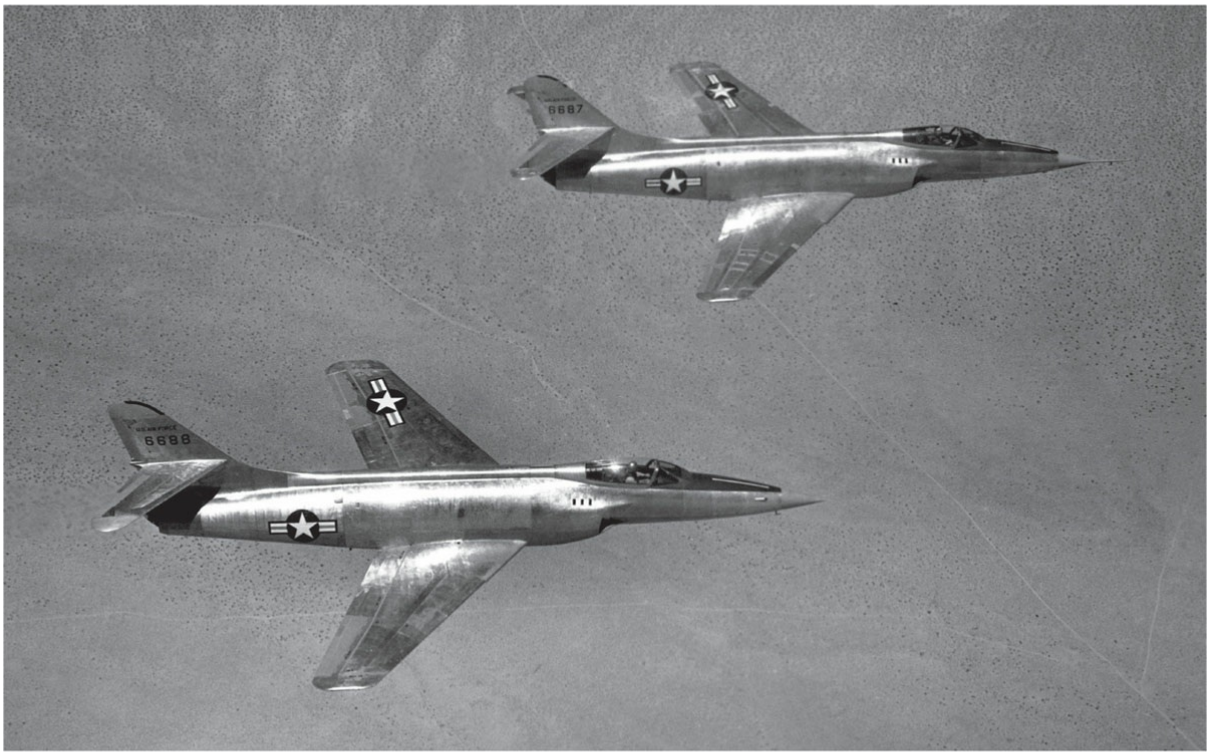
A view of the XP-90 at the Lockheed production facility at Burbank prior to its first flight. (EAFB/HO)



The XF-90 sporting a pair of general-purpose 500lb bombs. (Lockheed Martin)



The second prototype of the XF-90 being towed off from Rogers Dry Lake after a terminated test flight. (EAFB/HO)



Both XF-90s take to the air for this photo shoot as they fly in formation over the Mojave Desert. (Author's collection)

X-7

1951

X-17

1955

PROGRAMS: X-7A-1 • X-17

Name: X-7 Flying Stove Pipe

Mission: Ramjet testbed

Length: X-7A-1: 32ft 9in (9.98m); X-7A-3: 37ft (11.28m)

Wing Span: X-7A-1: 12ft (3.66m); X-7A-3: 10ft (3.05m)

Height: 7ft (2.13m)

Name: X-17

Mission: Re-entry test vehicle

Length: 40ft 5.5in (12.2m)

Wing Span: 8ft 6in (2.59m)

Height: N/A

Max T.O. Weight: 12,000lb (5,443.1kg)

Max T.O. Weight: 8,000lb (3,629kg)

First Flight: 26 April 1951

Last Flight: 20 July 1960

Crew: Unmanned

Number Built: 61

Power Plant: 1 x Marquardt XRJ-43-MA

First Flight: 23 May 1955

Last Flight: September 1958

Crew: Unmanned

Number Built: 30+ (airframes not recovered)

Power Plant: 1 x Thiokol XM20

Design Speed: Mach 4.3 (2,800mph; 4,500km/h)

Service Ceiling: 100,000ft (30,480m)

Combat Radius: 130 miles (112.9nm; 209.2km)

Weapons Load: N/A

Design Speed: Mach 14.5 (11,125mph; 17,904km/h)

Service Ceiling: 500,000ft (150km)

Combat Radius: N/A

Weapons Load: N/A

Lockheed Missiles & Space Company (LMSC) built the X-7 for the Skunk Works for the USAF to test technology for supersonic ramjet engines and missile guidance and control components. Dubbed "the flying stovepipe," the 33ft-long vehicle had a 12ft wing span and a diameter of 20in. The X-7 was carried aloft on an aircraft for aerial launch. The booster attached to the stern of the X-7 was ignited after launch and pushed the vehicle to approximately 1,000mph. The ramjet engine was mounted under the aft end of the fuselage. The ramjet being tested, slung underneath, then took over the propulsion, and the booster was jettisoned. B-29s and later B-50s were used as launch planes.

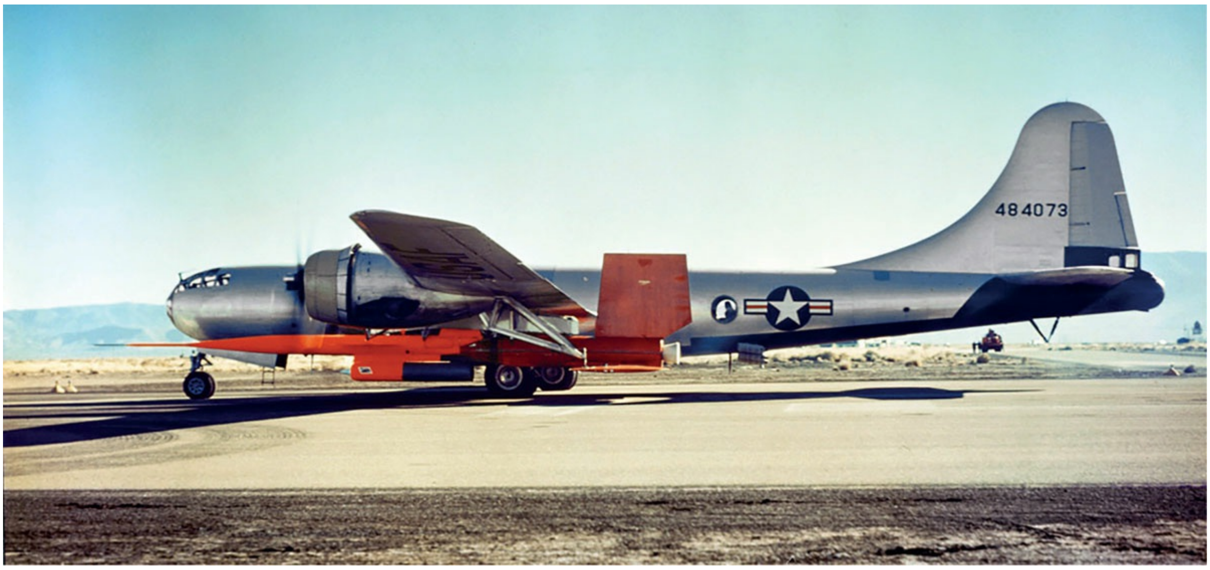
In a ramjet, there is no compressor. Instead, the forward speed of the vehicle is employed to "ram" air into the combustor. At supersonic speeds air enters the intake where a diffuser nozzle causes the air to slow down to around Mach 0.2 through a series of shock waves. This sudden slowing creates the pressure needed to operate the engine. Fuel is injected and burned with the aid of a flame holder. Since there is no compressor to power, there is no need for a turbine and the hot gases expand directly out of the nozzle. The downside is that the ramjet engine can only work when the vehicle is already moving at a considerable speed. A ramjet produces little thrust below about half the speed of sound and works best when operating at low supersonic speeds (ranging from Mach 1 to Mach 3).

Ramjets always offered far more promise than they actually delivered, and it was not until the late 1950s that the practical winged ramjet-powered aircraft became a reality, as exemplified by the Lockheed X-7 pilotless test bed and the Boeing IM-99 Bomarc SAM. First flown in April 1951, the last of its 130 flights occurred in July 1960. There were three main groups doing the engine research and conceptual work; Marquardt, Johns Hopkins University Applied Physics Laboratory, and General Applied Science Laboratory. Several companies were involved in engine development and production, and no fewer than seven major airframe companies were doing active design studies. One Marquardt ramjet had accelerated a Lockheed X-7 test vehicle to about Mach 4.7 in an all-out test, holding it at nearly 1g until the fuel ran out. But the recovered engine and airframe were badly overheated, and not reflyable.

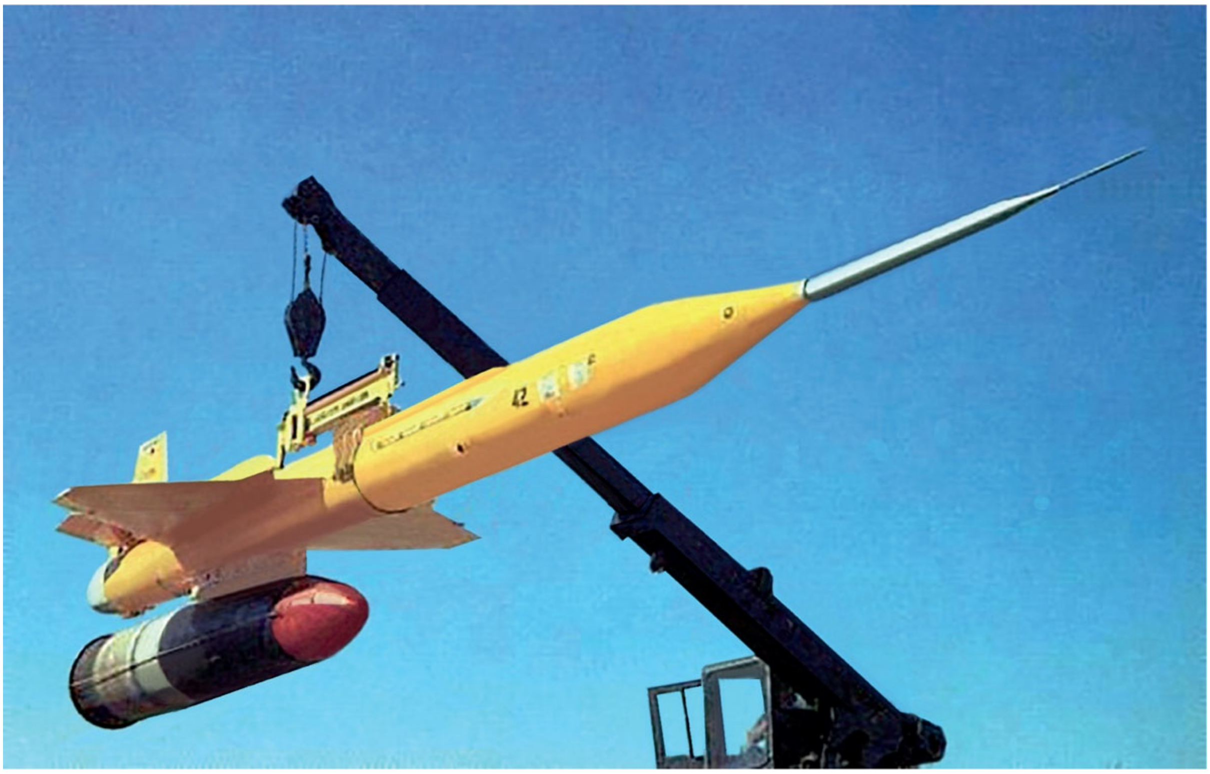
Marquardt completed their scheduled production of the ramjet engine for the Bomarc A missile in 1960. As this program phased out, production began immediately on the new RJ43-ll engine, which powered the new Bomarc B missile in successful test flights. This advanced ramjet engine and its predecessor, the RJ43-3, were the only two ramjets in the nation to have passed the military qualification test. In mid-1960, final flight-testing of the RJ43-ll was completed when the engine met all flight requirements as it propelled the Lockheed X-7 test vehicle on a complex flight. The X-7 has acted as a flying test bed for air-breathing engines. After flight, a parachute recovery system lowers both missile and engine to earth, where complete evaluation can be made.

During a 13-year testing program, the X-7 flew and reflew ramjet engines and components, simulating Bomarc flight parameters to test and prove the Marquardt propulsion system's reliability before qualifying it for Bomarc service. Powered by a single ramjet engine, the X-7 reached speeds in excess of Mach 4, more than 3,000mph, and it established a world altitude record for air-breathing missiles by exceeding 100,000ft. More significant than these speed and altitude records is the contribution which the ramjet development and testing programs made to advance the state of missile and engine art.

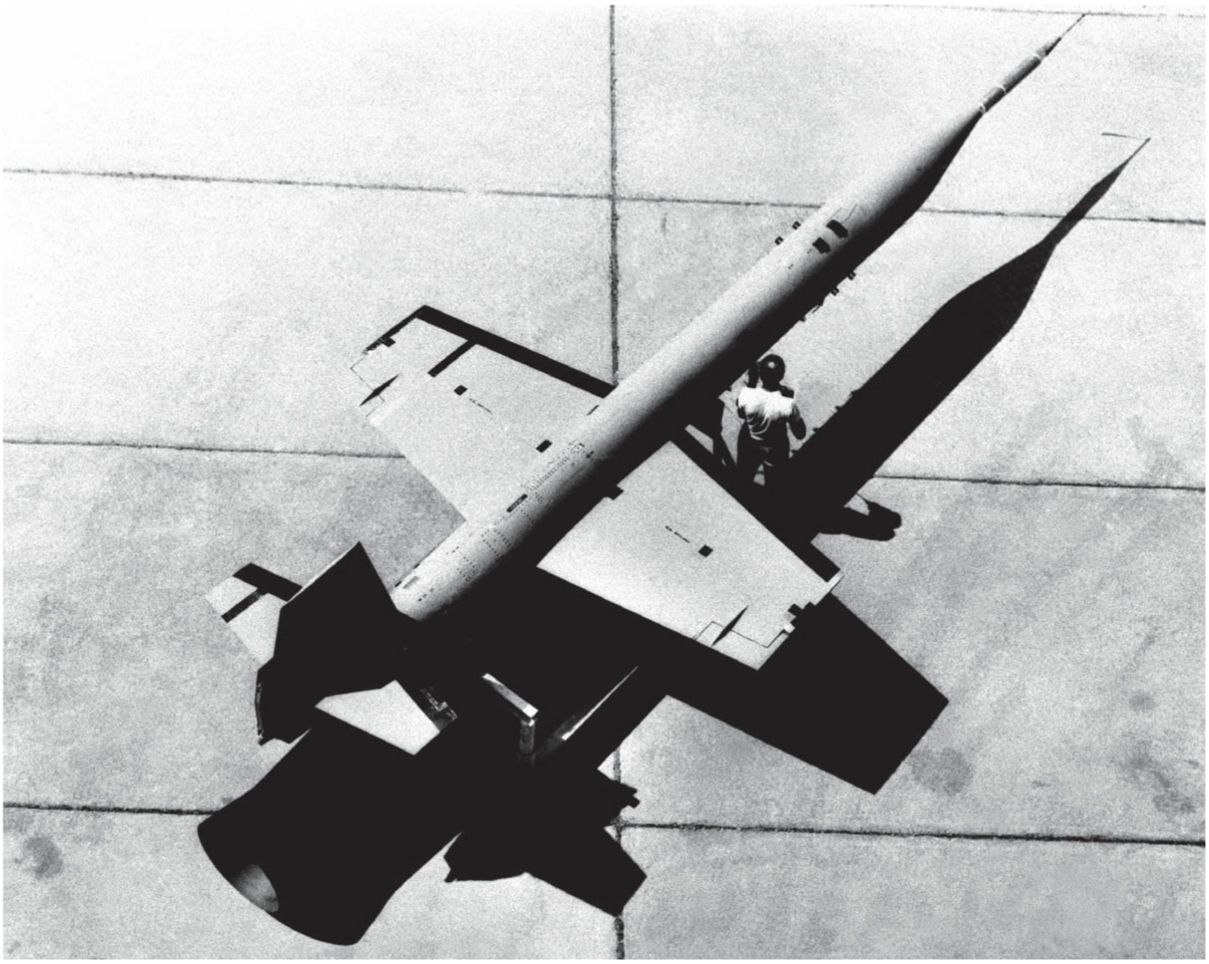
At the end of their missions, the missiles deployed parachutes, and their sharp, aerodynamic nose spikes buried themselves vertically into the ground. Later on, this flight-test program suffered its only casualty. Thankfully, it was not serious. There were cattle near by White Sands in those days and the aerospike nose of an X-7 skewered a steer.



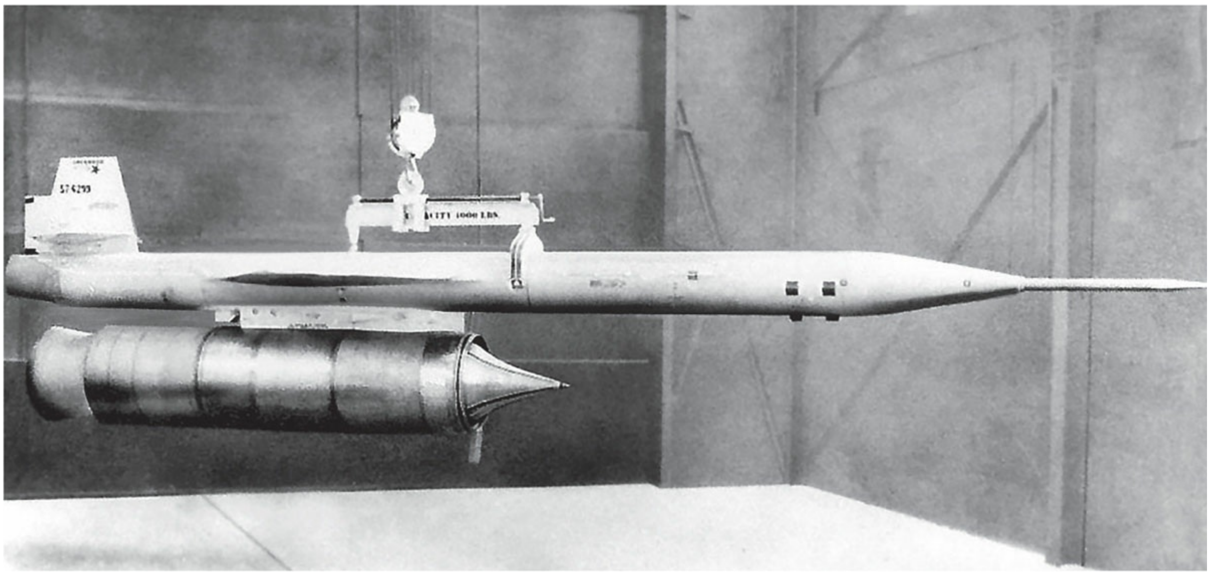
The ramjet test craft, the Lockheed X-7A, is shown attached to the port wing of the RB-29J launch plane on the south end of Edwards runway. (EAFB/HO)



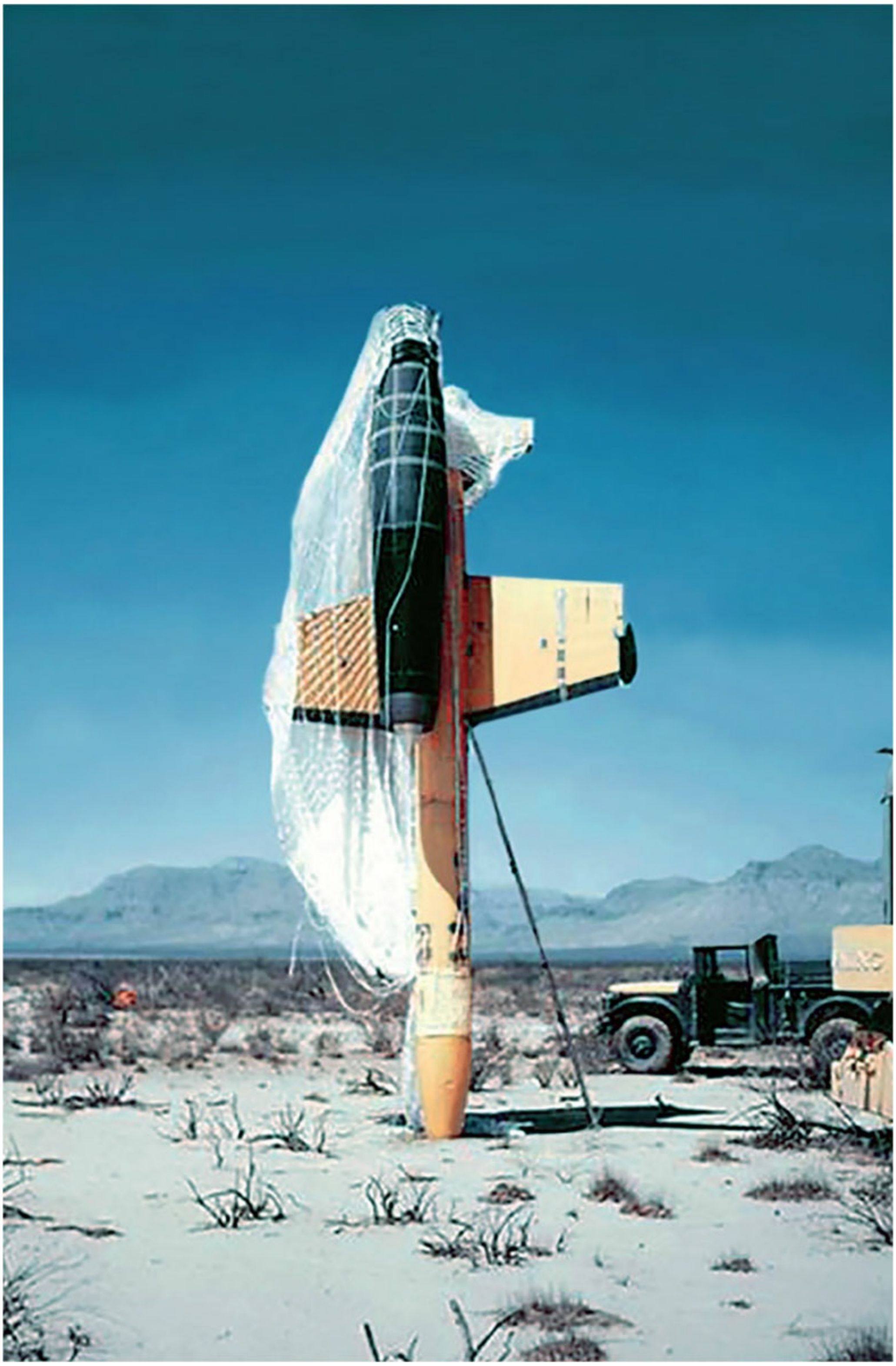
The most advanced version of the X-7A is the X-7A-3. This version offered much-improved performance in the form of increased range and endurance, and a higher maximum top speed. (Author's collection)



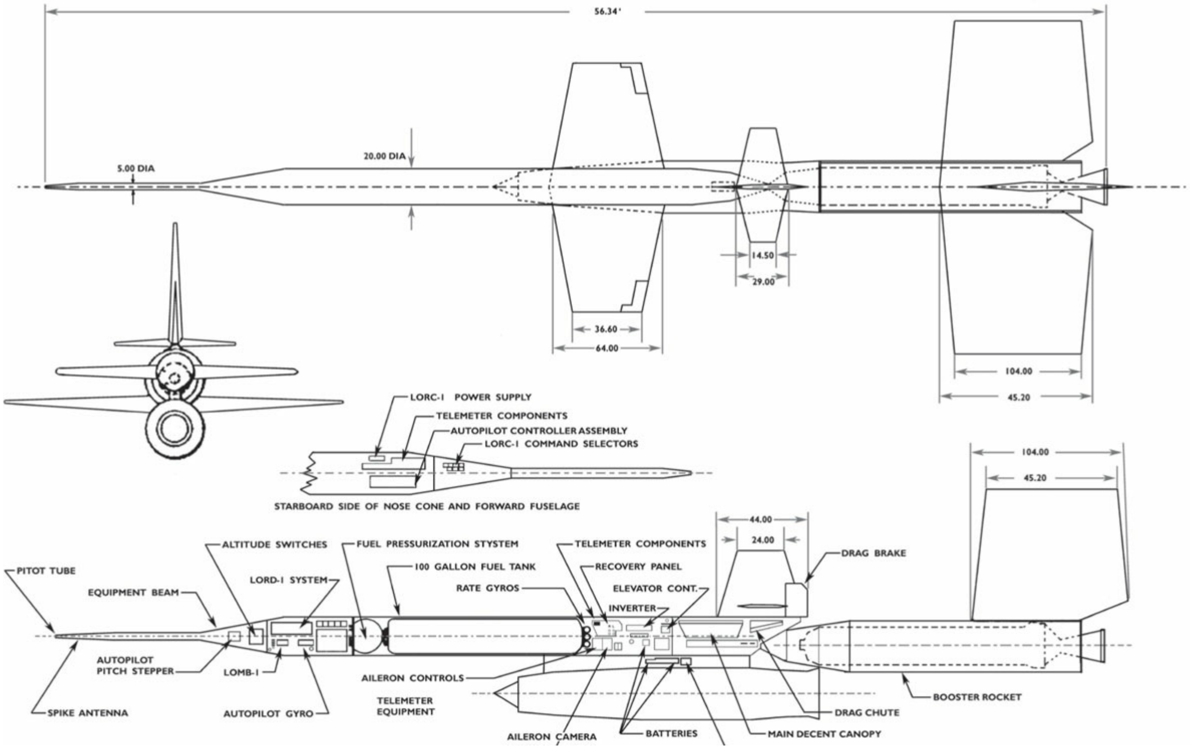
A look-down view of the X-7A on the ramp of Marquardt, the maker of the ramjet that powered the craft. The low-aspect ratio wing and exceptionally small ailerons are seen to good effect. Also note the unusual vertical fin-mounted air brake. (Author's collection)


LOCKHEED
57-6299
CAPACITY 4000 LBS.

A side view of the Lockheed X-7A-3 sporting the much larger Marquardt XRS-59-MA-24D ramjet. (Author's collection)



The way the X-7 was recovered was to deploy a large ribbon parachute with its aim to land the X-7 on its structurally reinforced nose probe. (EAFB/HO)


56.34'
5.00 DIA
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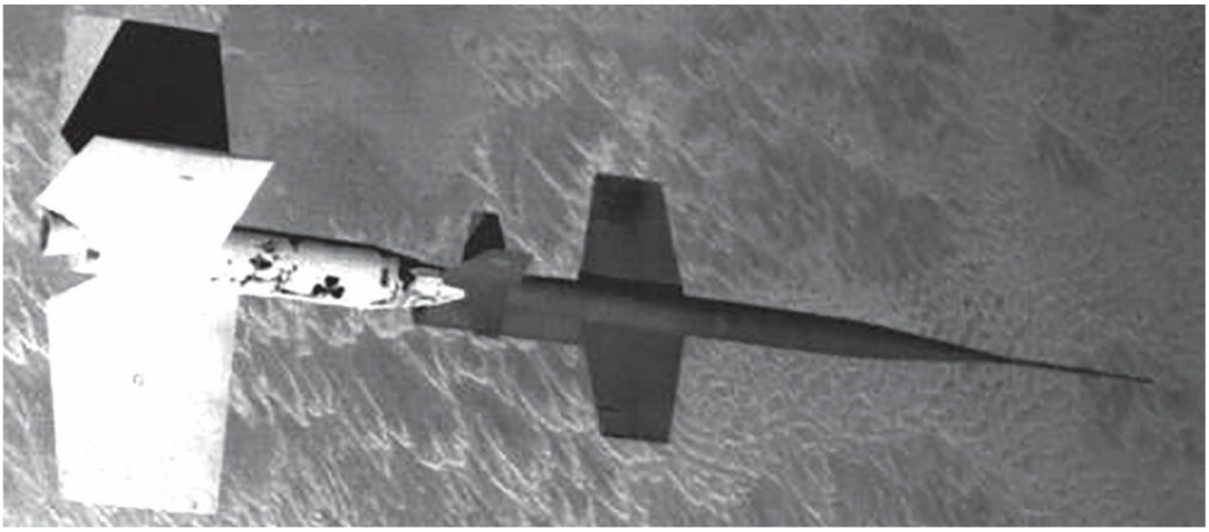
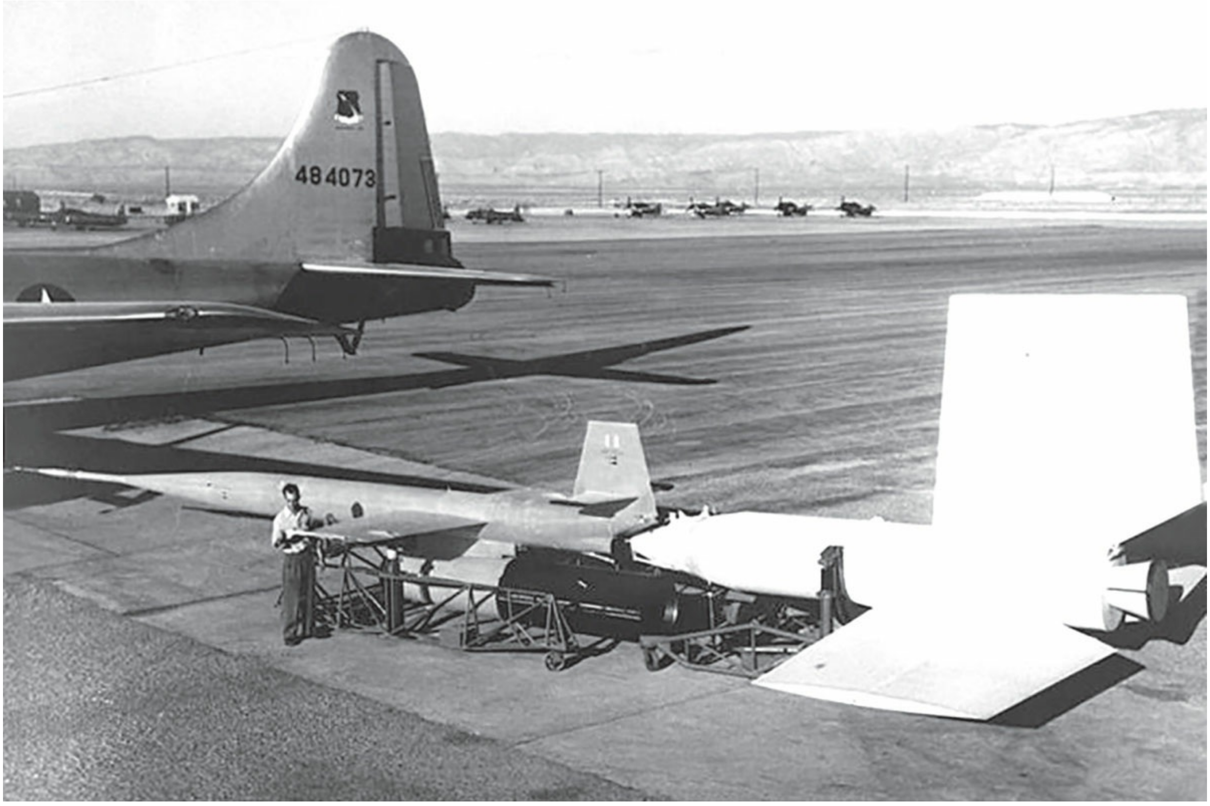
14.50
29.00
36.60
64.00
104.00
45.20
LORC-1 POWER SUPPLY
TELEMETER COMPONENTS
AUTOPILOT CONTROLLER ASSEMBLY
LORC-1 COMMAND SELECTORS
STARBOARD SIDE OF NOSE CONE AND FORWARD FUSELAGE
104.00
45.20
44.00
24.00
PITOT TUBE
EQUIPMENT BEAM
ALTITUDE SWITCHES
LORD-1 SYSTEM
FUEL PRESSURIZATION STYSTEM
100 GALLON FUEL TANK
RATE GYROS
TELEMETER COMPONENTS
RECOVERY PANEL
ELEVATOR CONT.
INVERTER
DRAG BRAKE
AUTOPILOT PITCH STEPPER
LOMB-1
AILERON CONTROLS
TELEMETER EQUIPMENT
SPIKE ANTENNA
AUTOPILOT GYRO
AILERON CAMERA
BATTERIES
MAIN DECENT CANOPY
DRAG CHUTE
BOOSTER ROCKET

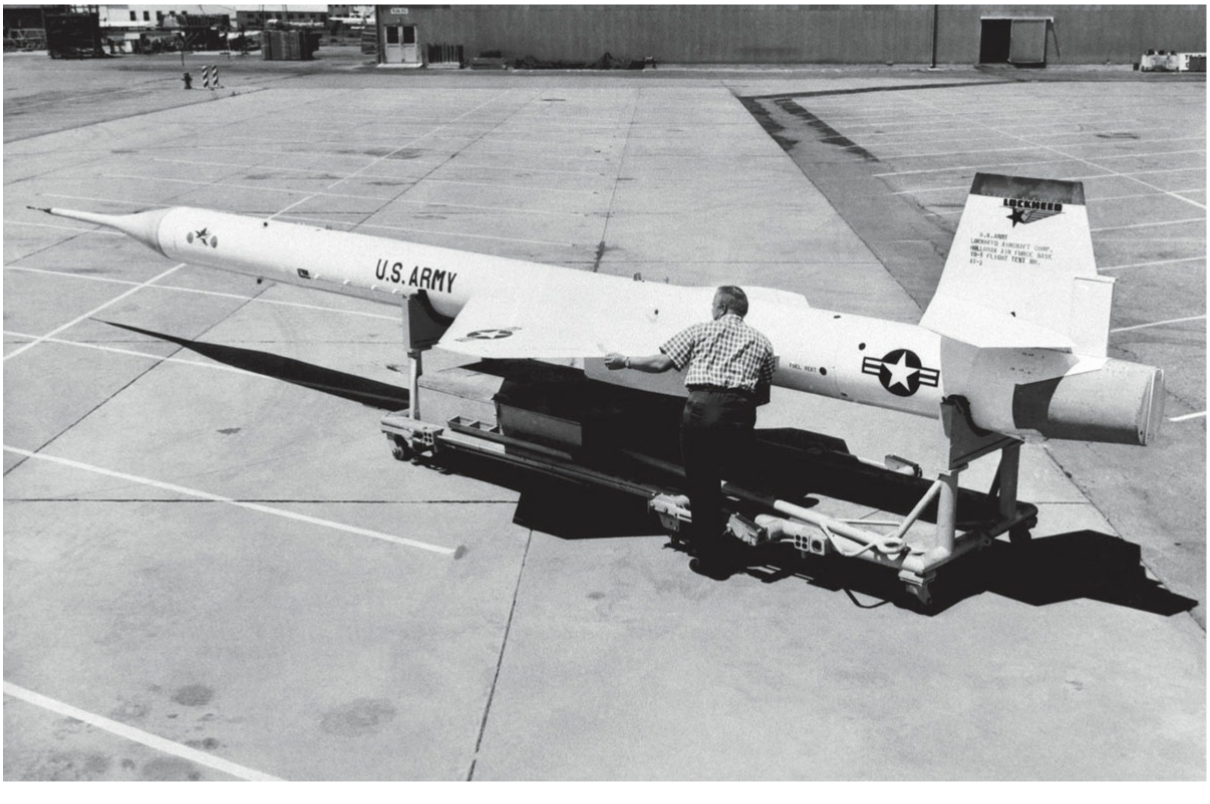
A drawing of the X-7 with booster. (James C. Goodall)

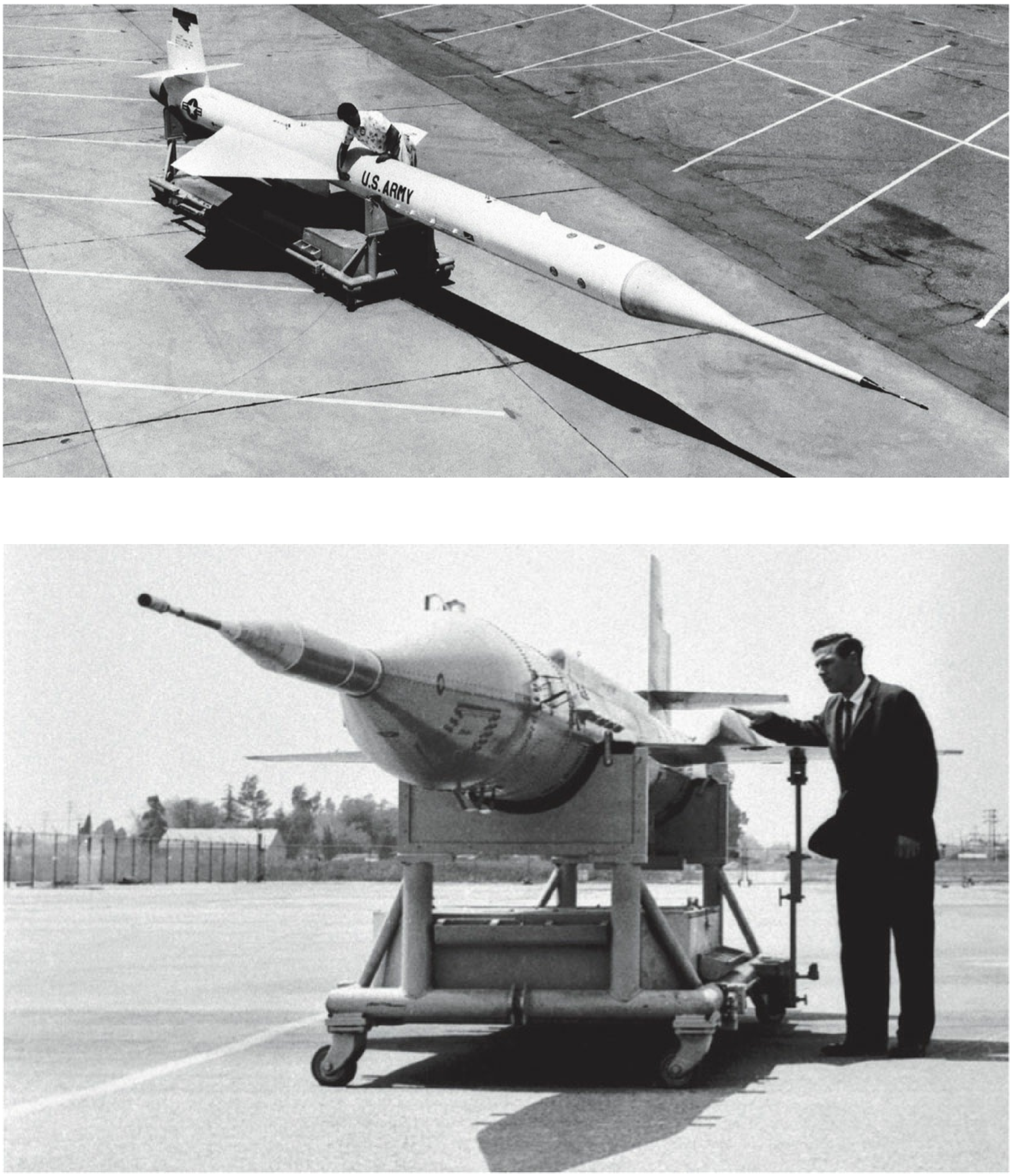


From a launch camera mounted on the port wing pylon of the RB-29J "Mother" aircraft. The solid-fuel booster unit was basically a very large JATO bottle with wings and was parachute recovered much like the X-7. (Author's collection)

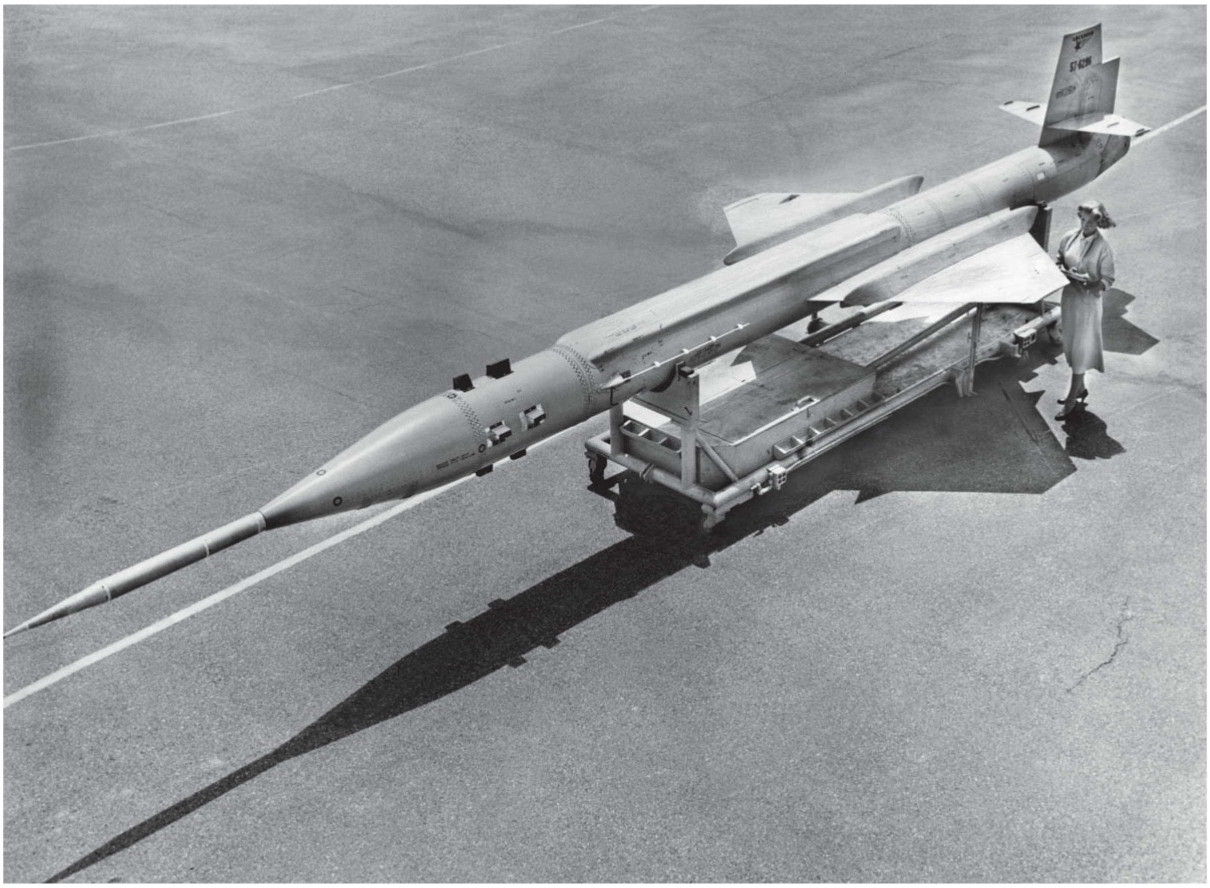


An X-7 on the ramp at Holloman AFB, NM, prior to being mated to the launch aircraft. (Author's collection)


U.S. ARMY
LOCKHEED



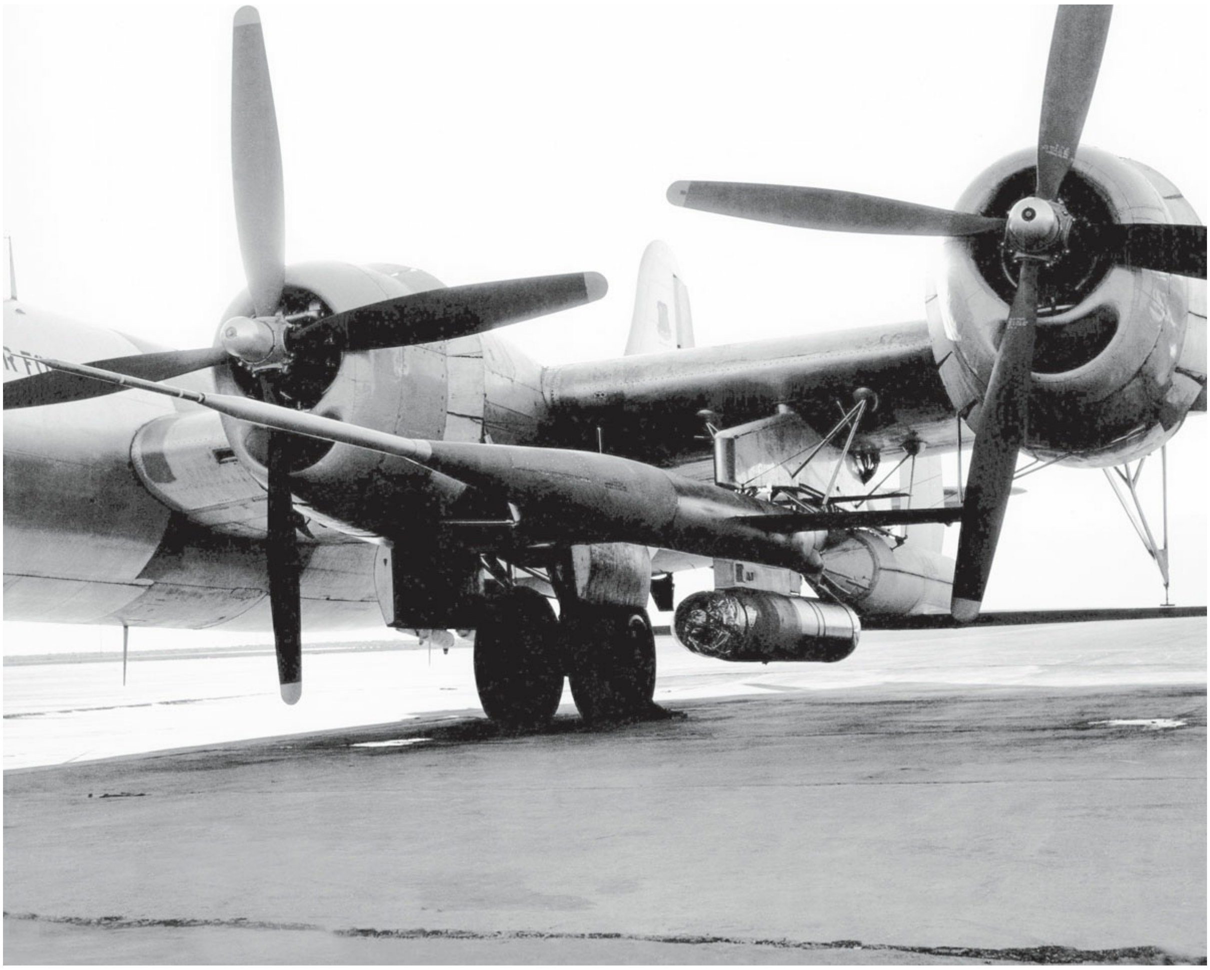
The US Army's XQ-5 was a smaller version of the X-7 and, like X-7, was powered by a Marquardt ramjet. It is photographed here in the company's parking lot at Van Nuys Airport, CA. (Author's collection)



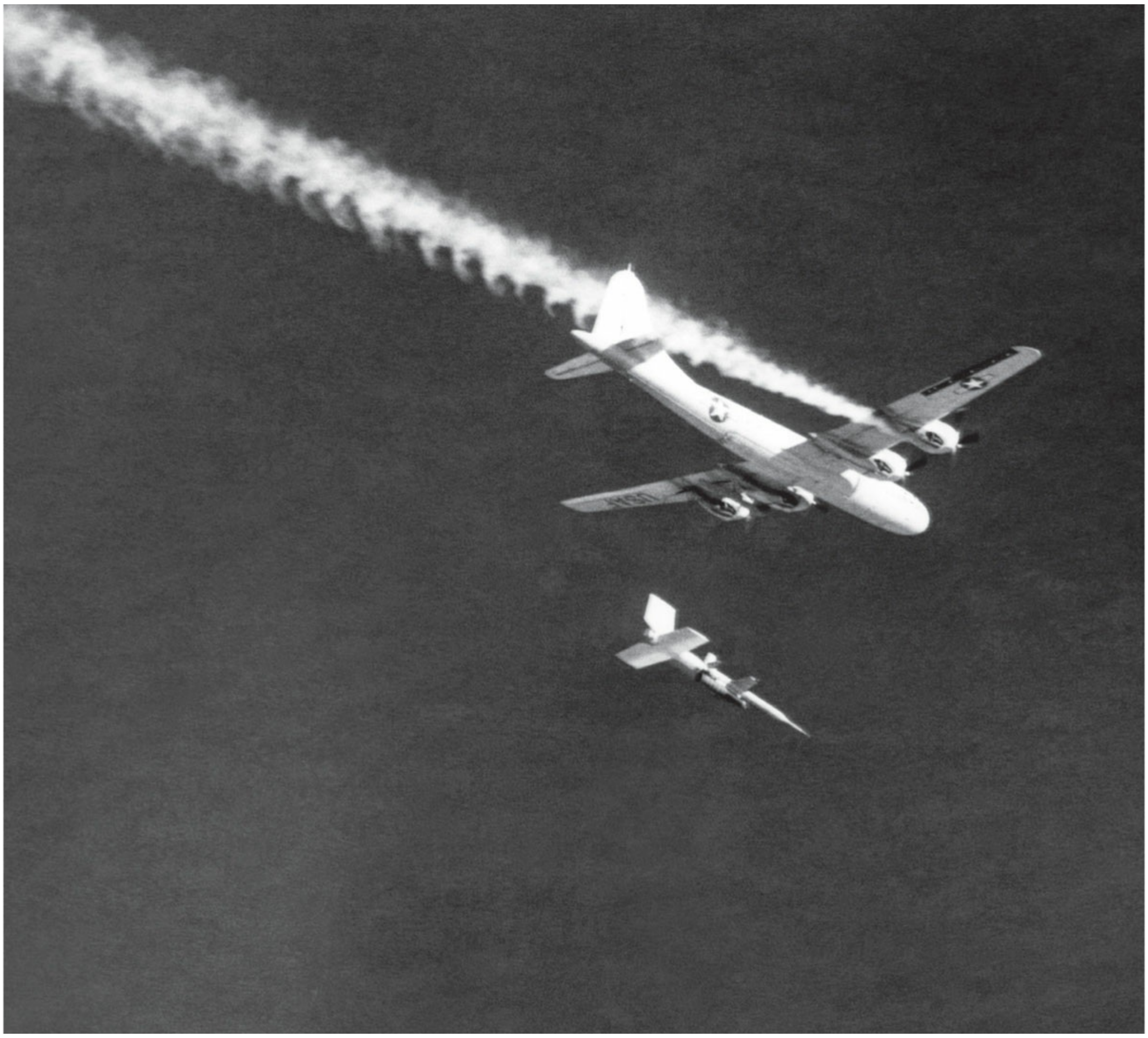
An X-7 on the ramp at Marquardt's facility with a port-side view of the basic X-7 in 1958. (Lockheed Martin)

USAF
484073

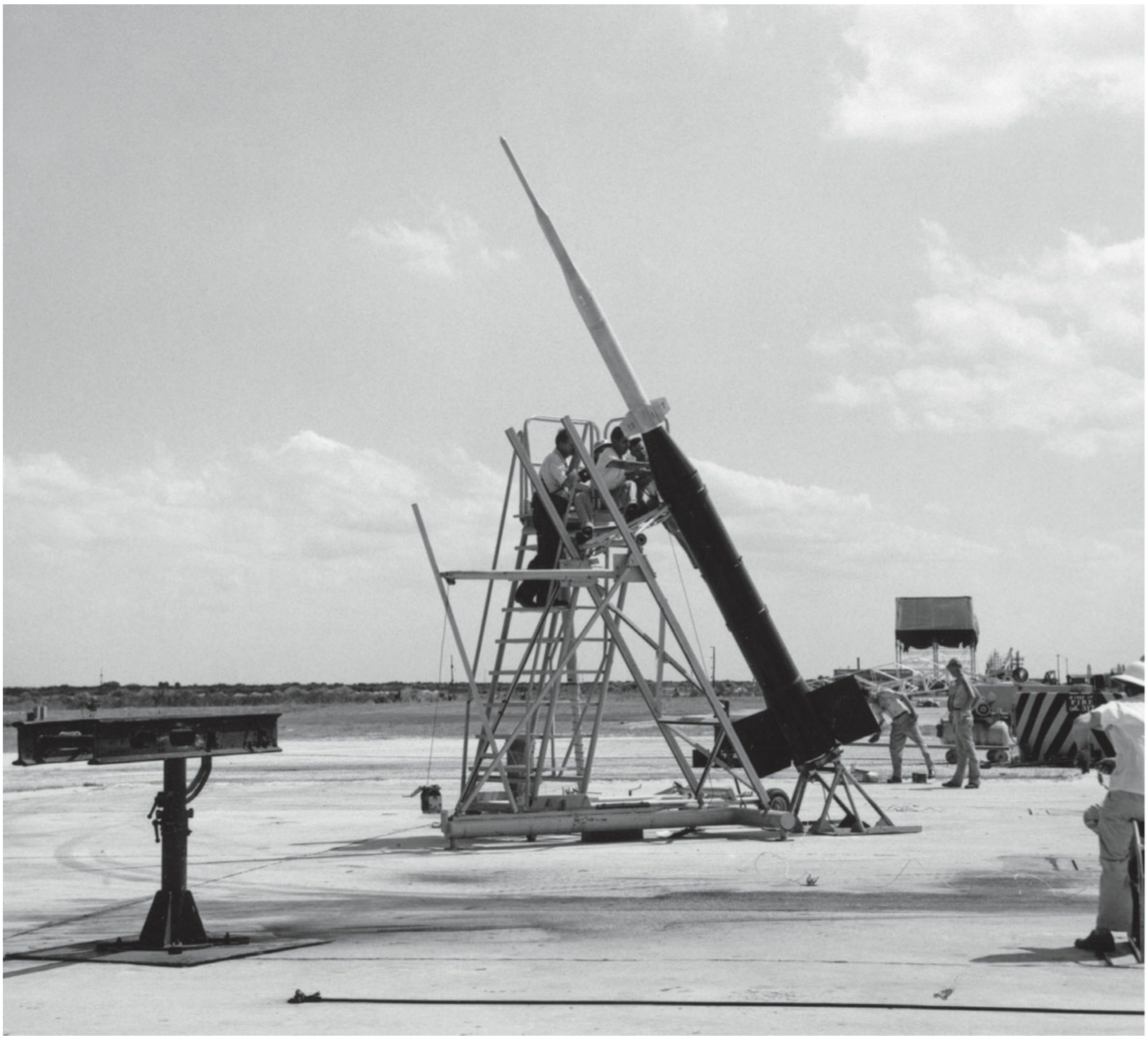
The USAF/Boeing RB-29J launch aircraft takes off from the Holloman AFB runway with the assistance of a gaggle of six JATO bottles. (Lockheed Martin)



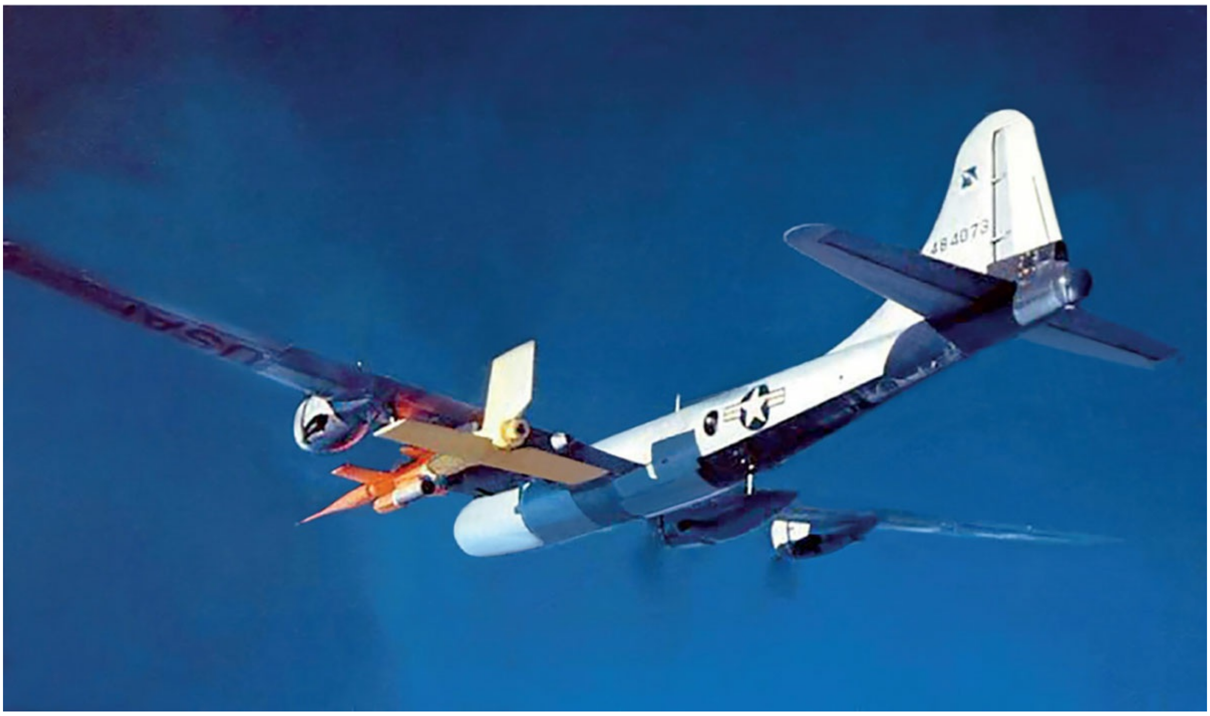
A good view of the booster support structure on the X-7A-1 taken on 7 May 1952. The early X-7As were powered by a Wright TV-3 XRJ47-W-1 ramjet versus the later use of the Marquardt-made ramjets. (Lockheed Martin)



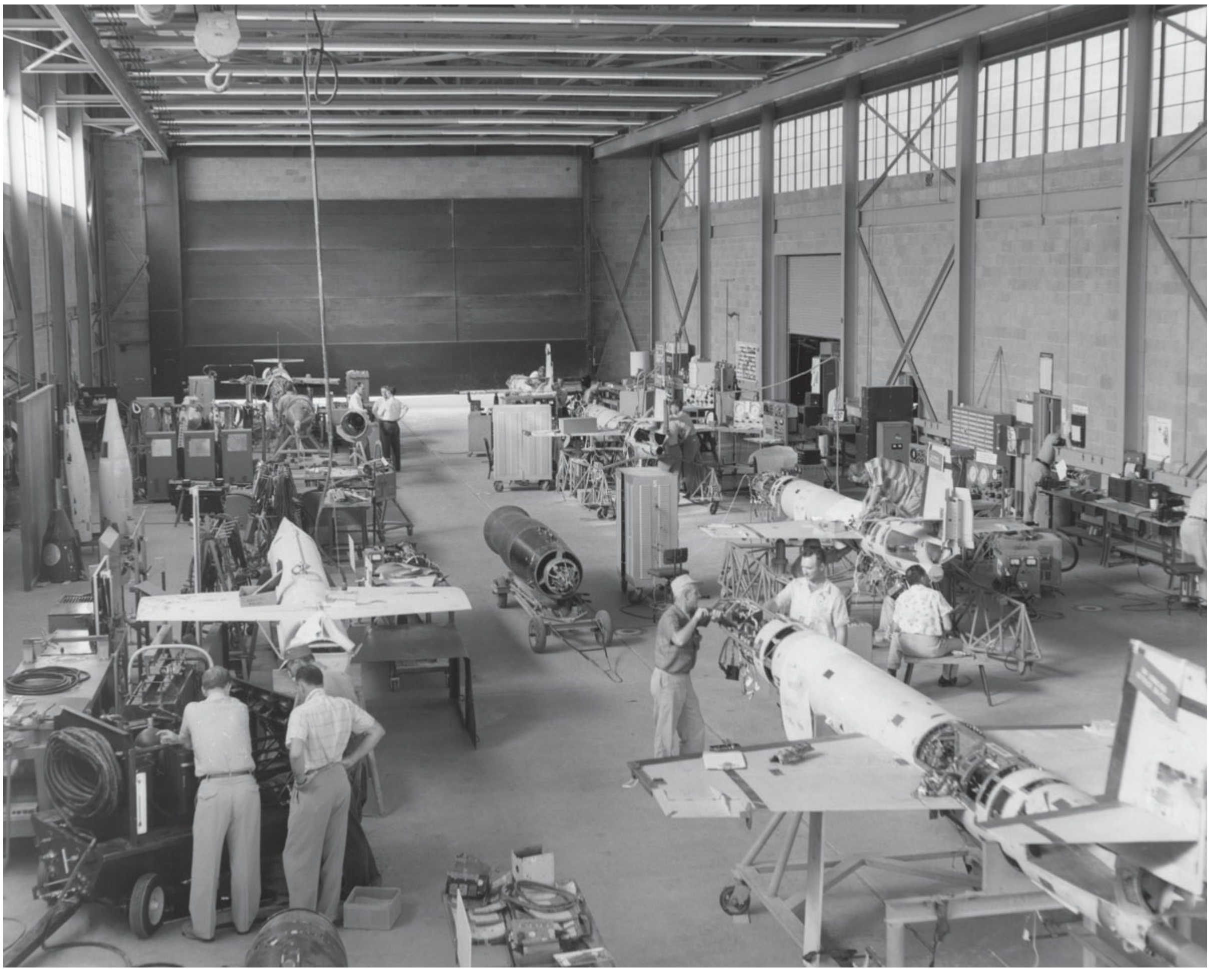
On 28 April 1953, the very first X-7A-1 was taken aloft under the wing of the "Mother" craft Boeing RB-29J. At altitude it was released and, after a five-second freefall, the booster ignited. Shortly after the release, the X-7 came apart and almost caused the loss of or damage to the launch aircraft. (Author's collection)



On 14 June 1955, Lockheed tried several ground launches of the X-7A-1 with limited results. These ground launch test flights were done at Cape Canaveral AFB, FL. (45th Space Wing)

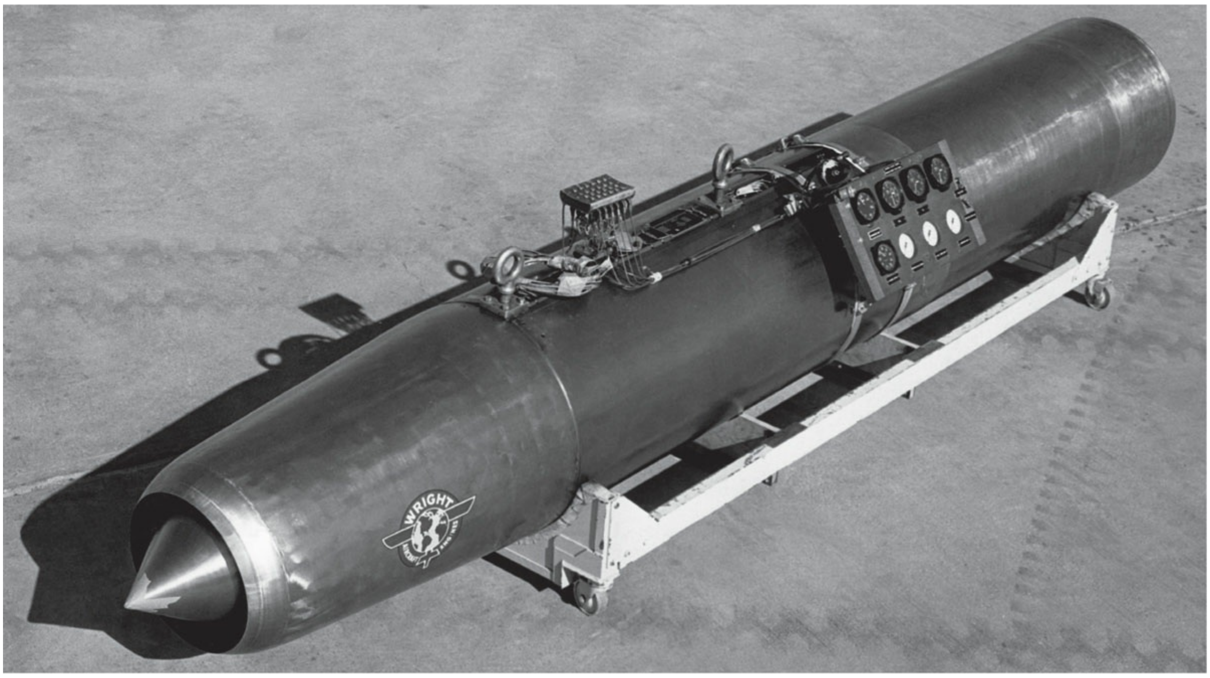

USAF
484073

A bottom view of the very colorful X-7A-3 under the wing of its launch aircraft. (Author's collection)

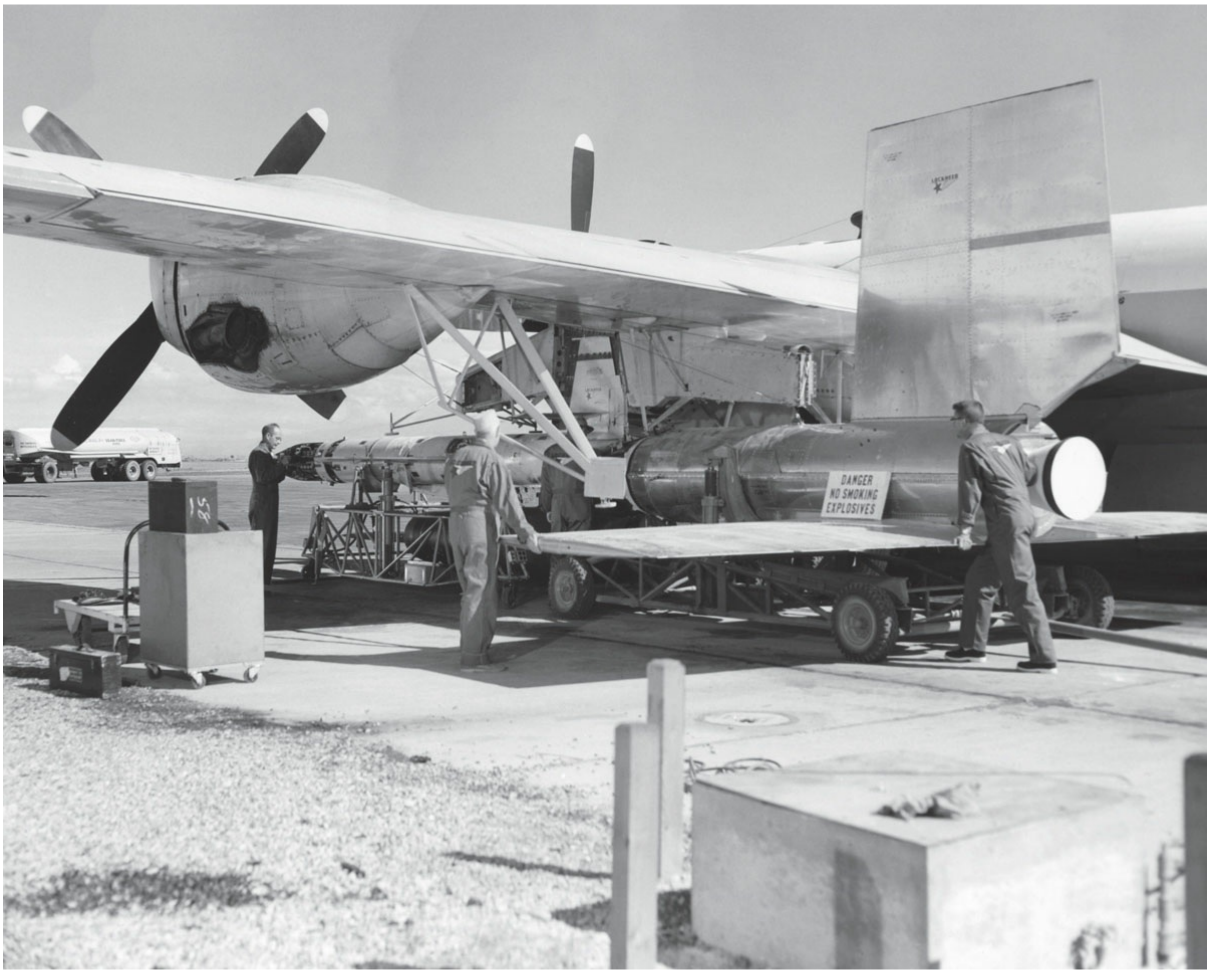


Most of the launches of the X-7 were carried out at Holloman AFB, which was also the site of the recovery operations. This photo, taken in the fall of 1957, shows at least six X-7s in various stages of assembly after recovery. (NARA)

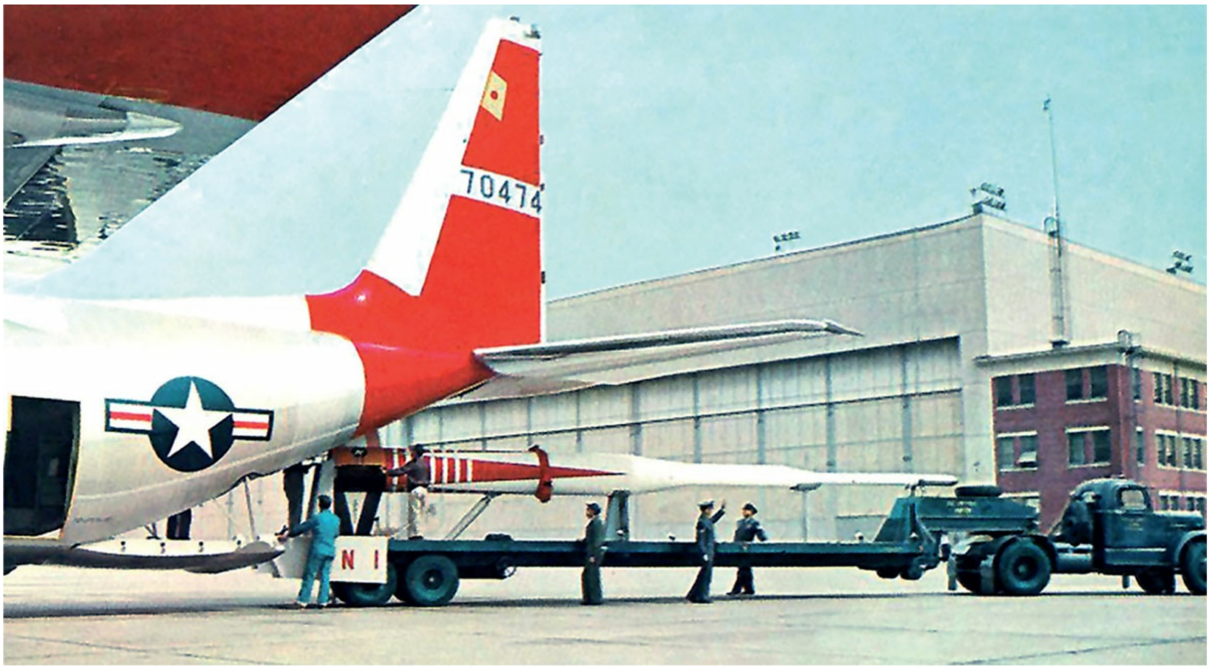
What is left of the X-7's booster after the recovery parachute failed to deploy, not much to recover. (Lockheed Martin)



Seven early launches of X-7As were powered by a Wright TV-3 XRJ47-W-1 ramjet before the move over to the Marquardt ramjets. (Author's collection)


DANGER
NO SMOKING
EXPLOSIVES

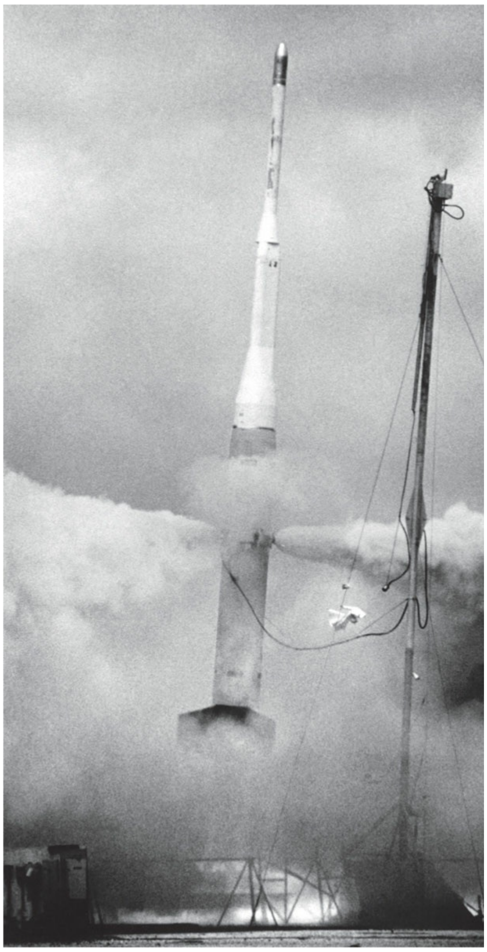
On the ramp at Holloman AFB, NM, the Lockheed team preps the advanced version of the X-7A-3. Due to the large size of the booster's vertical fin, it was decided early on to launch the X-7 from the air. (Lockheed Martin)



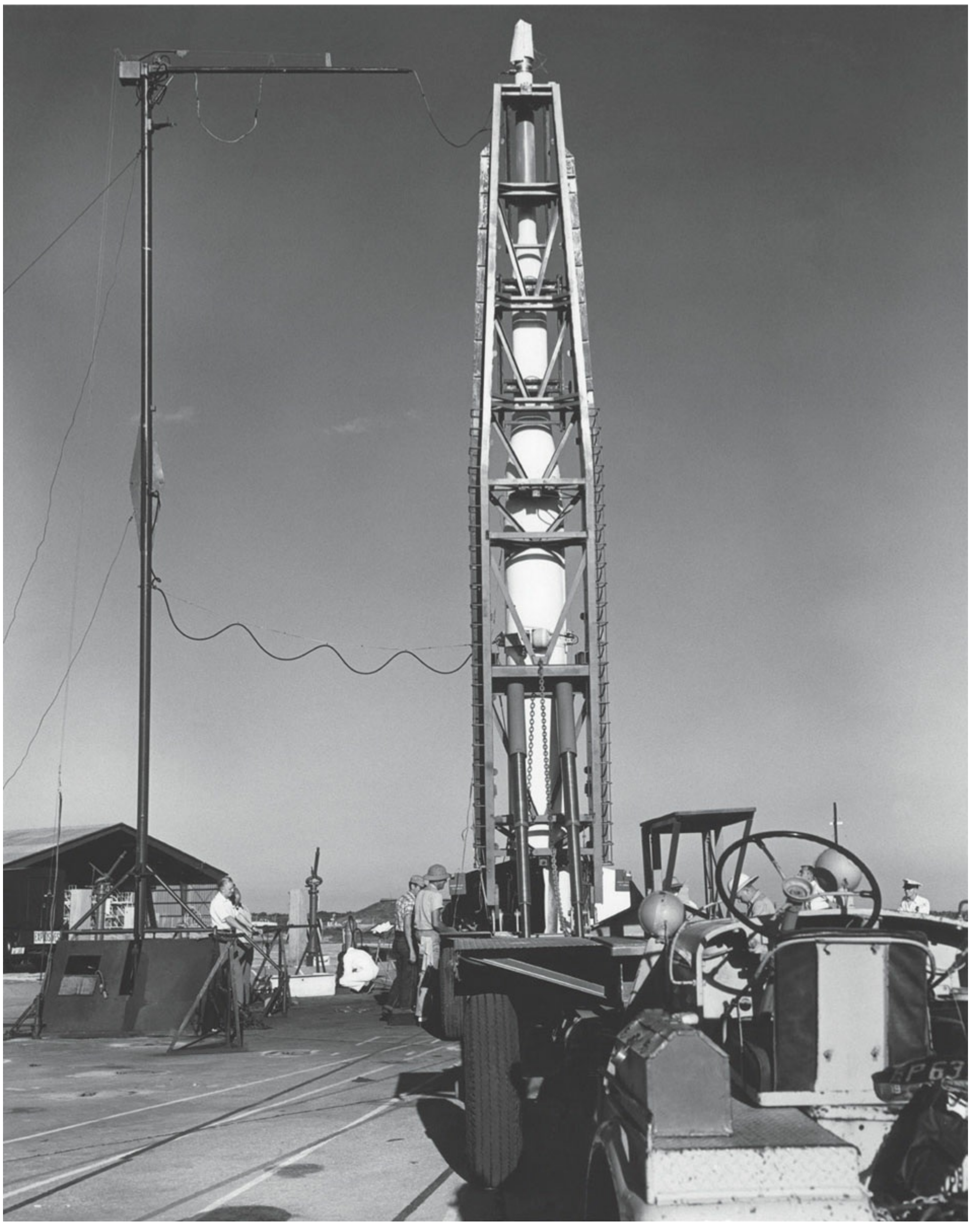
A completed X-17 is carefully loaded into a Lockheed C-130A at Patrick AFB, FL, prior to being transported to Cape Canaveral AFB. (Author's collection)

EXPLOSIVES

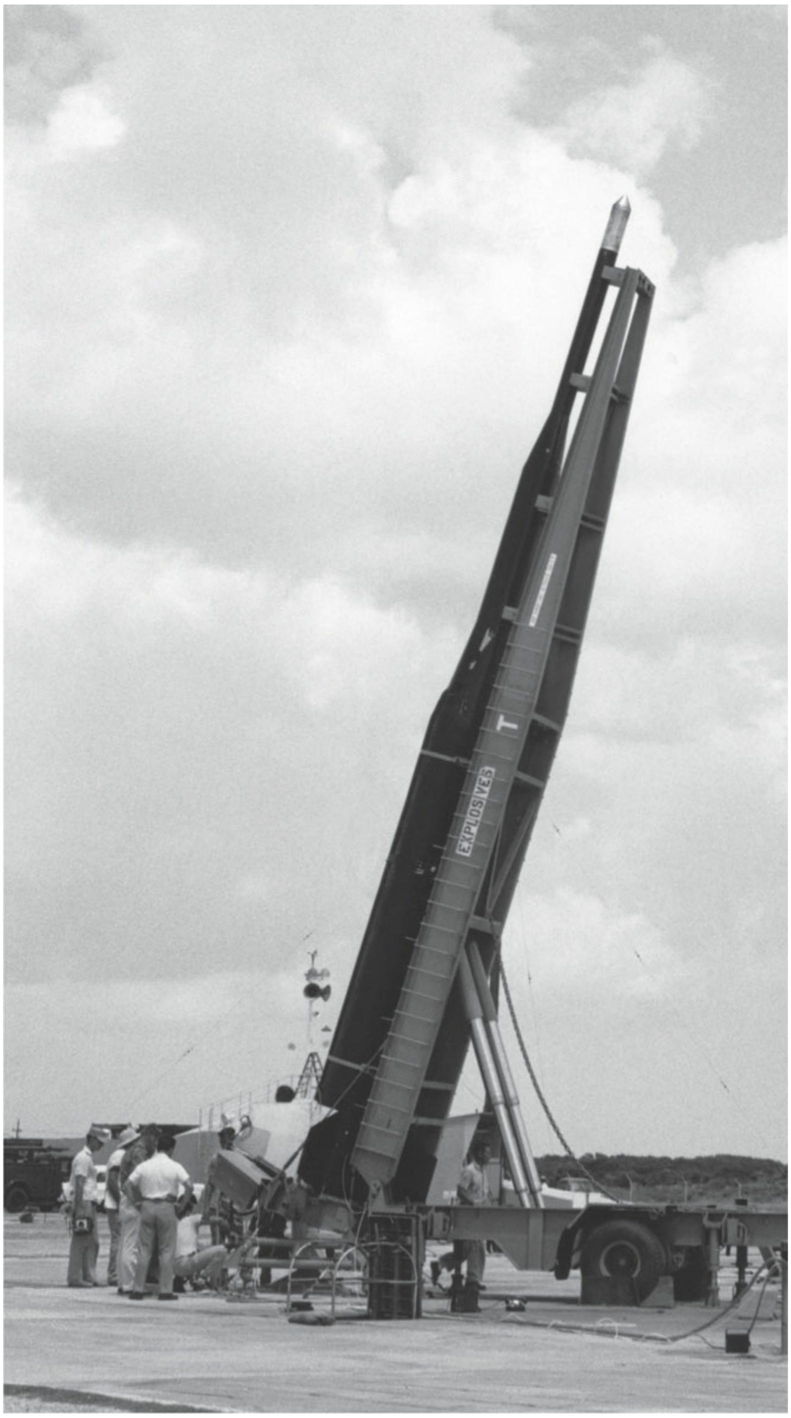
The X-17 on the dedicated trailer prior to being erected for a vertical launch. (NARA)



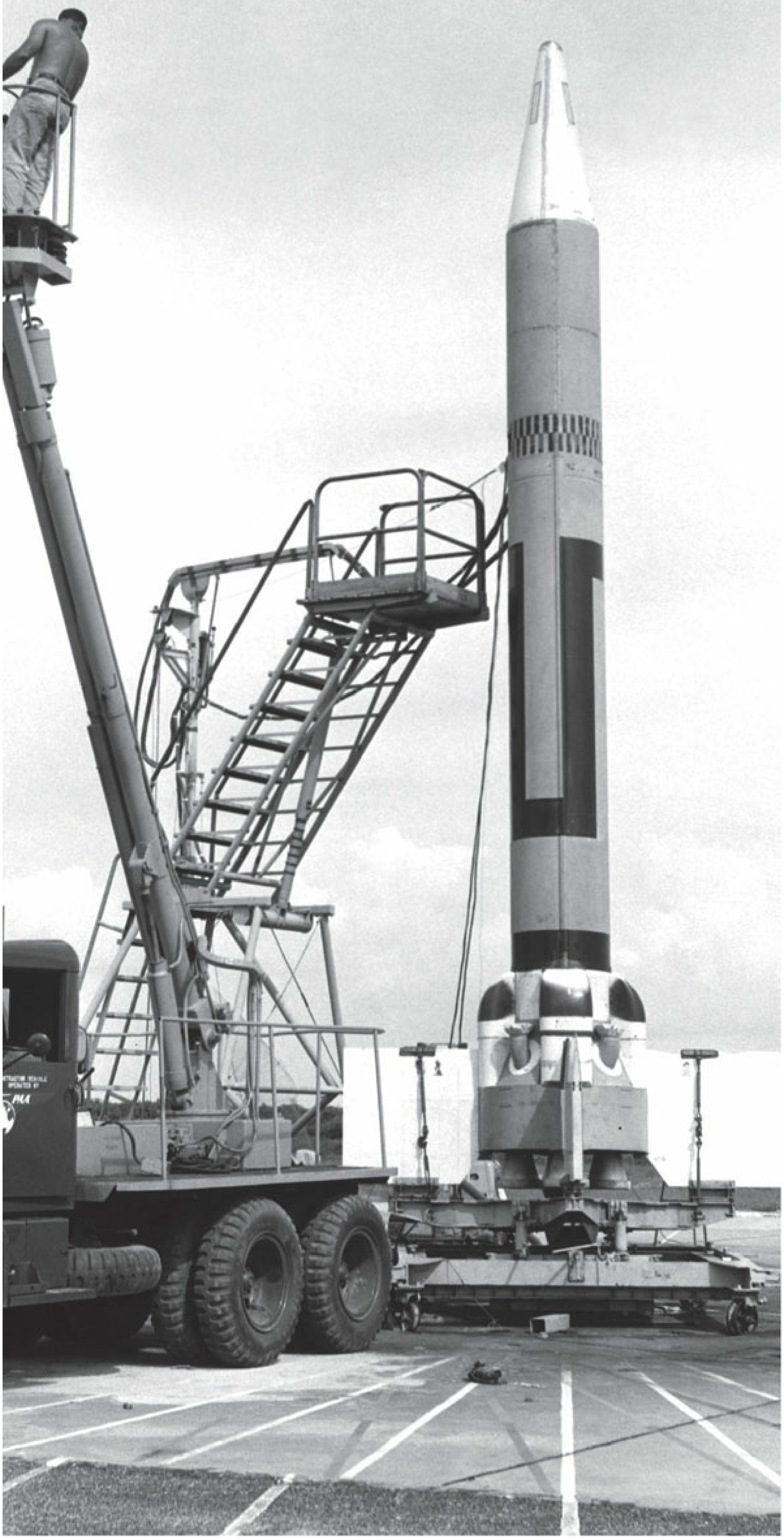
A Fourth of July 1957 launch for the Lockheed-developed X-17. (NARA)



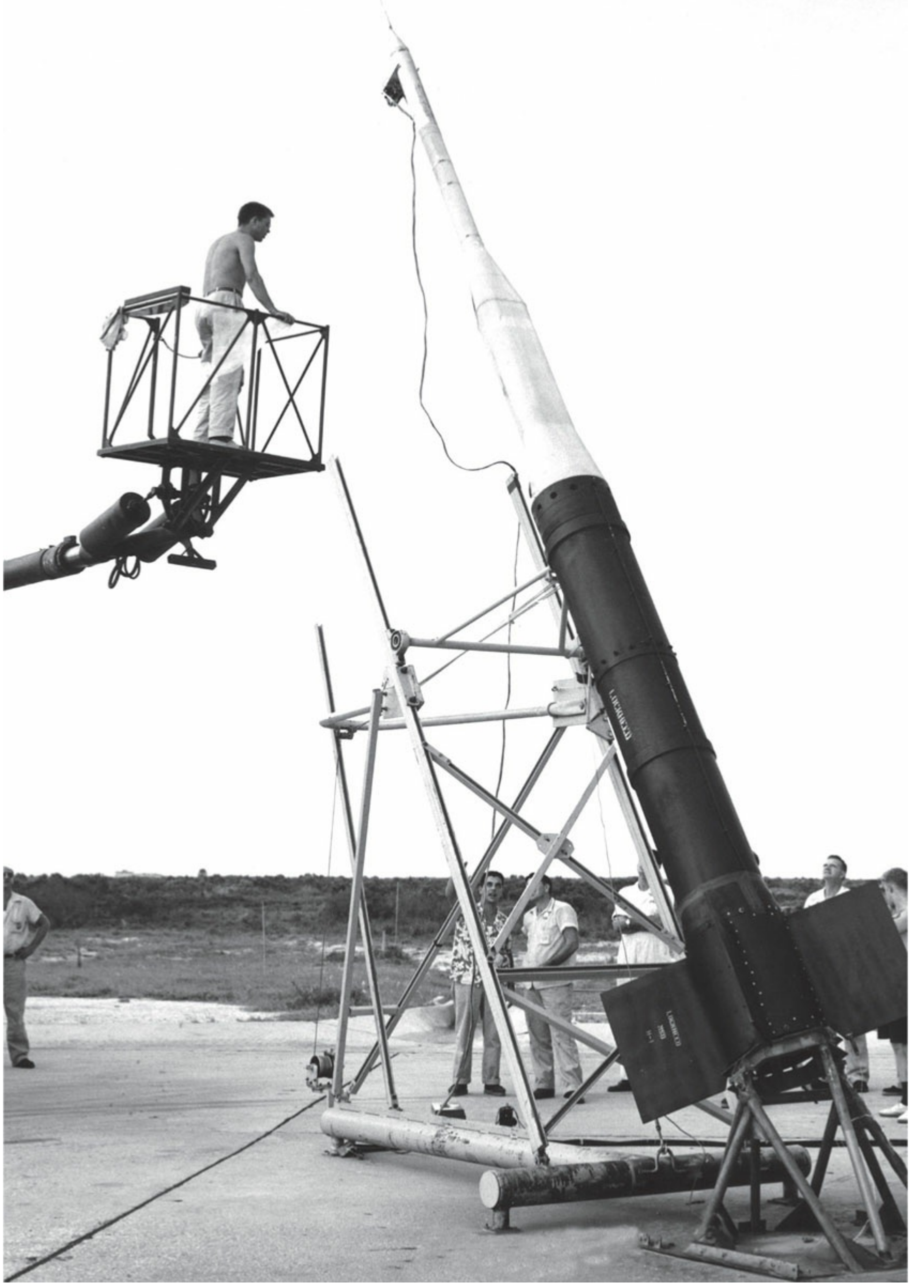
An X-17 test launch on 23 August 1957 at Cape Canaveral AFB.


EXPLOSIVES
T

X-17 test number 1111 at Cape Canaveral AFB, being erected and ready for a test flight. (Lockheed Martin)



X-17 test launch prep on 29 August 1957 on Pad 3 at Cape Canaveral AFB. (NARA)



X-17 test launch prep on 24 June 1955 at Cape Canaveral AFB. (NARA)

YC-130 HERCULES

1954

PROGRAM: C-130

Name: Hercules

Mission: Tactical airlift

Length: 97ft 9in (29.79m)

Wing Span: 132ft 7in (40.41m)

Height: 38ft 3in (11.66m)

Max T.O. Weight: 155,000lb (70,307kg)

First Flight: 23 August 1954

Last Flight: Still in production

Crew: 5 on classic C-130s; 3 on “J” models

Number Built: 2,500+ and still in production through 2040

Power Plant: 4 x T56-A-15 turboprops; C-130J models: Rolls-Royce AE 2100 D3 turboprop

Design Speed: Mach 0.44 (336mph; 541km/h)

Service Ceiling: 33,000ft (10,000m) empty; 23,000ft (7,000m) w/max load

Combat Radius: 2,360 miles (2,050nm; 3,800km)

Weapons Load: AC-130: 1 x 155mm cannon, 2 x 40mm; MC-130: GBU-43/B MOAB

It can be said without fear of contradiction that the C-130 Hercules is one of the most important aircraft in aviation history.

Since its first flight in 1954, the Hercules has been everywhere and done just about anything. Aircrews have flown it to both poles, landed or airdropped military supplies to hot spots from Vietnam to Afghanistan and performed countless relief operations around the globe. The Hercules has been used to drop bombs, retrieve satellites in midair, conduct reconnaissance and attack ground targets with cannons. Some models are flown as commercial transports. The C-130 boasts the longest continuous military aircraft production run in history and one of the top three longest continuous aircraft production lines of any type. It is believed that the C-130 family of airlifters will still be in production in 2040.

Those who design, build, fly, support and maintain a Hercules often say that the plane is without a doubt the world's most proven workhorse, and for good reason. To date, more than 2,500 C-130s have been ordered and/or delivered to 63 nations around the world. Countries that operate C-130s have produced more than 70 different variants.

From landing on the highest of airstrips in the Himalayas to touching down on aircraft carrier runways in the middle of the ocean, the C-130 regularly and proudly defies expectations. The Hercules is known for its ability to tackle any mission, anywhere, at any time.

As the US entered into the Korean War, the USAF realized that it did not have a true military transport capable of airlifting combat troops over medium distances and delivering them to short, austere airfields. To fill this need, the USAF Tactical Air Command issued a specification in early 1951 for a new medium cargo transport.

The then-Lockheed Aircraft Corporation won the competition and was contracted to produce two prototype YC-130 aircraft on 2 July 1951. The first flight of YC-130 took place on 23 August 1954, at Lockheed's Burbank plant. Its four turboprop engines enabled the YC-130 to take off in only 800ft. In addition to its tremendous lift capability, the aircraft also proved to be far more maneuverable than expected while meeting or exceeding all of the other USAF performance requirements.

The success of the prototypes led to a production contract. As the Burbank facility was at capacity, the entire C-130 program was moved to Lockheed's facility, then known as the Lockheed-Georgia Company, in Marietta, Georgia. The first production C-130A, which was nearly identical to the prototypes, was flown for the first time at Marietta on 7 April 1955. The C-130A featured four powerful Allison T56-A-lA turboprop engines, each delivering 3,750hp and driving a three-bladed Curtiss-Wright electric-reversible propeller.

From the beginning, the C-130 has featured a large, unobstructed, fully pressurized cargo hold that can rapidly be reconfigured for the carriage of troops, stretchers or passengers, or for the airdrops of troops and/or equipment into battle zones. The C-130's high-wing design places the cargo floor at truck-bed height above the ground. The C-130 also features an integral "roll-on/roll-off" rear-loading ramp. Coupled with its tremendous lift capacity, long range, and austere landing field capabilities, it is a true tactical airlifter.

The C-130 airframe was immediately recognized for its incredible versatility, prompting it to be quickly adapted for use in supporting special mission requirements. The first of some 70 different variants, namely a ski-equipped version for resupplying Distant Early Warning radar sites, was initially tested in 1957. No matter the mission, no matter the location, Hercules has gone there, is going there and will go back there thanks to its constant state of innovation. Today's C-130s are ready for tomorrow's missions.

The C-130 continues to be the world's standard for tactical airlift needs, especially in the form of the C-130J Super Hercules. The Super Hercules offers superior performance and new capabilities, with the range and flexibility for every theater of operations and for evolving requirements. To date, 16 countries operate or will operate the C-130J, which has been used to set 54 world aviation records.

The C-130J family includes 11 variants and it can support more than 16 different mission requirements. The Super Hercules continues to expand its offerings with the addition of the C-130XJ (baseline version of the C-130J), and the LM-100J, the updated Super Hercules version of the commercial L-100.

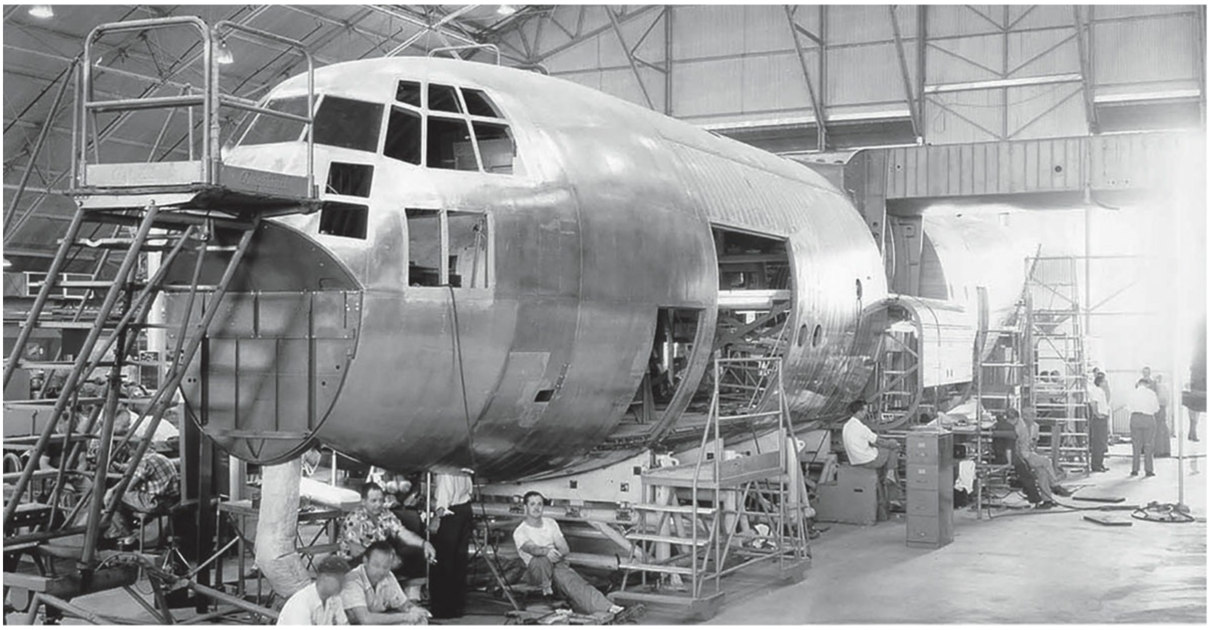
With the Super Hercules worldwide fleet logging more than 1 million hours of flying combat, humanitarian, special operations, aerial refueling, firefighting, and search and rescue missions around the world, the C-130J stands ready for its next mission and for whatever the future holds.

33397
UNITED STATES AIR FORCE

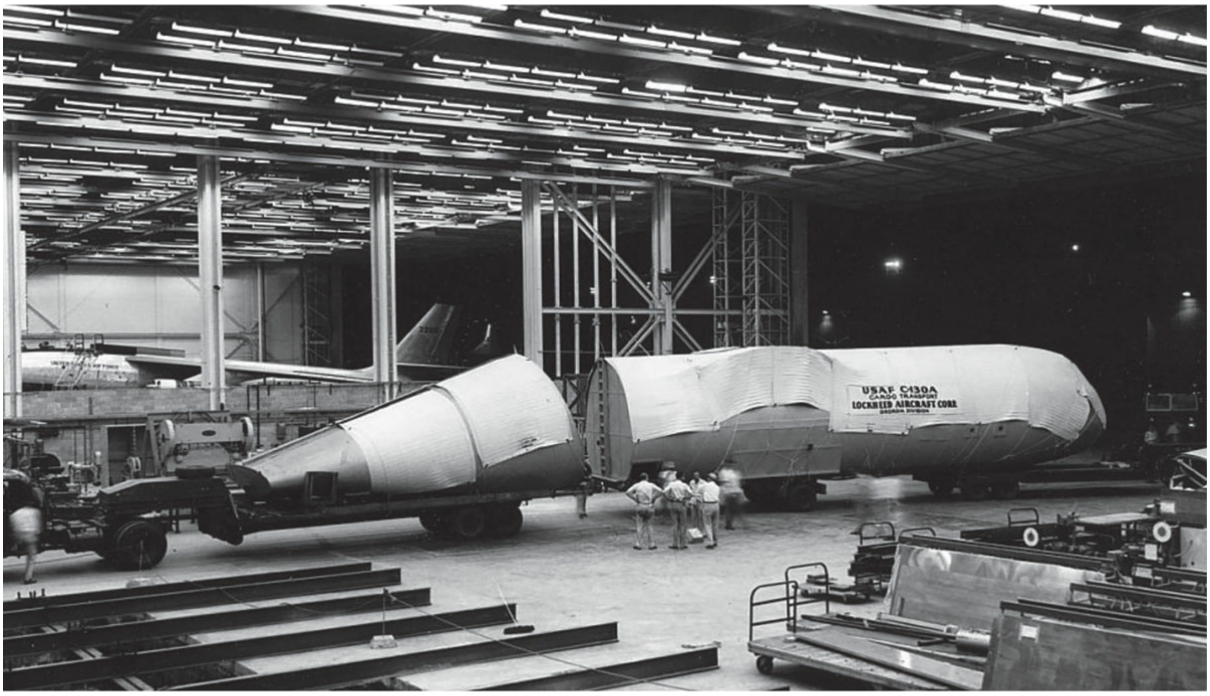
A great view of the prototype YC-130 over the San Gabriel Mountains east of Los Angeles. (Lockheed Martin)

33397
UNITED STATES AIR FORCE

Though Kelly Johnson retained considerable reservations about the viability of the C-130 as a production military transport his concerns were unfounded. Since the beginning of production in 1953 Lockheed Martin has delivered over 2,600 C-130s of all types. (Lockheed Martin)



Lockheed mechanics take a break after completing the fuselage mating operations of the first YC-130, the prototype of the C-130 Hercules, on 2 July 1953. The large opening in the fuselage is for a side-opening cargo door that was later deleted on production C-130s. (Lockheed Martin)


USAF C-130A
CARGO TRANSPORT
LOCKHEED AIRCRAFT CORP.

The C-130 mockup arrives in the final assembly building of the then Lockheed-Georgia Company in Marietta, GA, in 1953. The reassembled mockup was used to fine-tune the Hercules design and test systems for fit. After serving for several years, the mockup was eventually scrapped. (Lockheed Martin)

U.S. AIR FORCE

The first production C-130 is being preflighted prior to its first flight on 7 April 1955. (Lockheed Martin)

UNITED STATES AIR FORCE

The prototype YC-130 flight-test team waits for the okay from Operations to take to the air for its first flight. (Lockheed Martin)

33397
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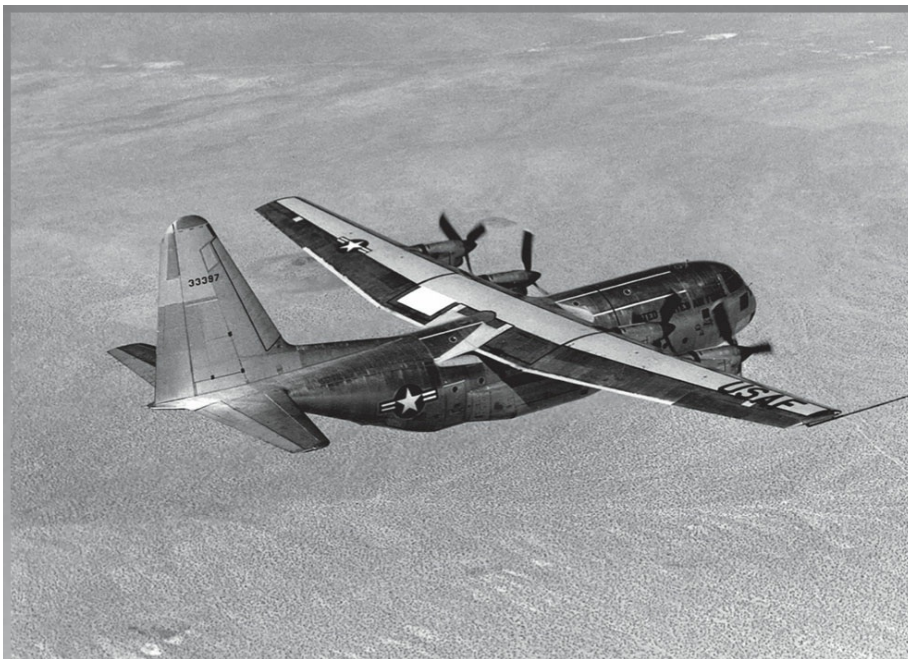
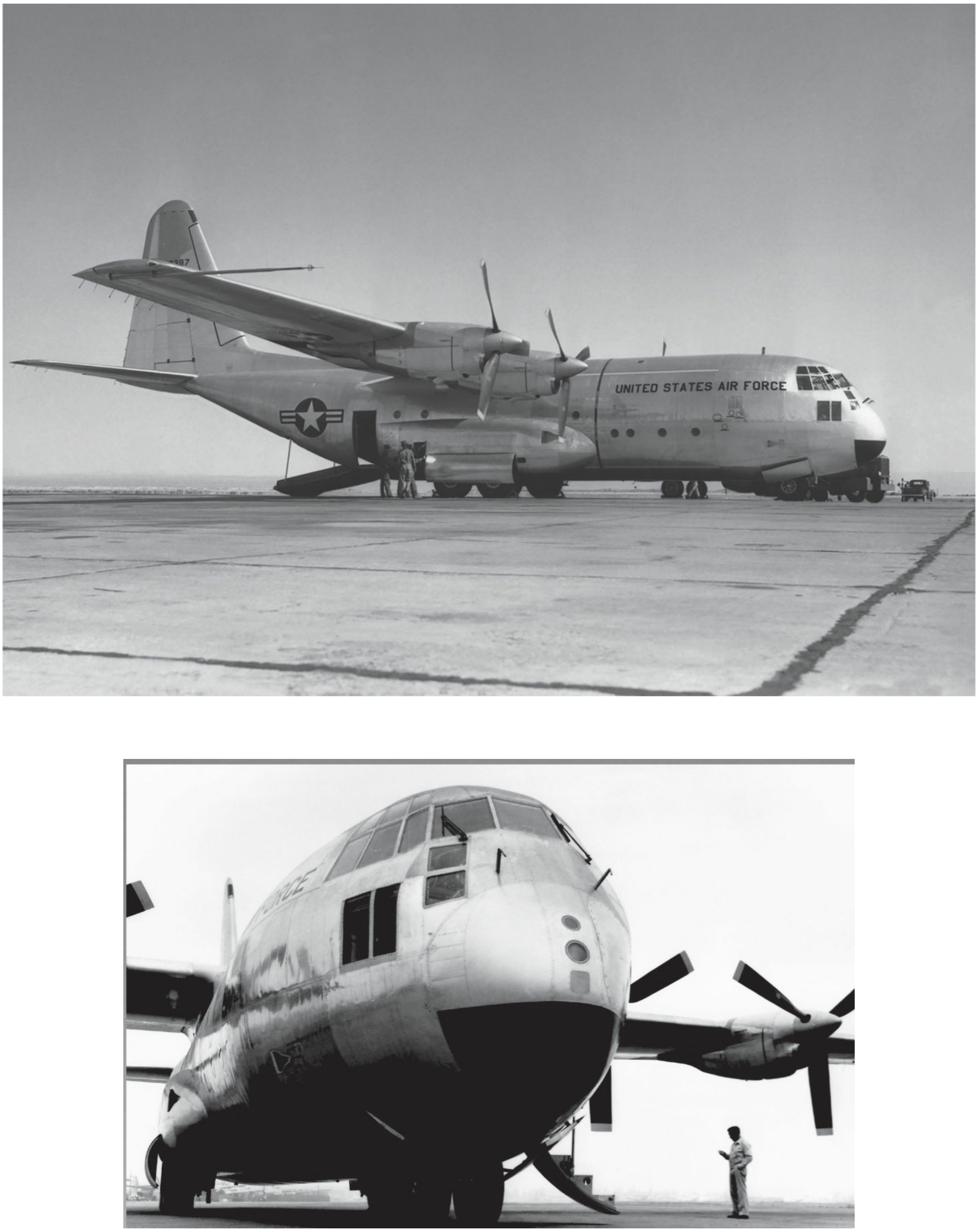
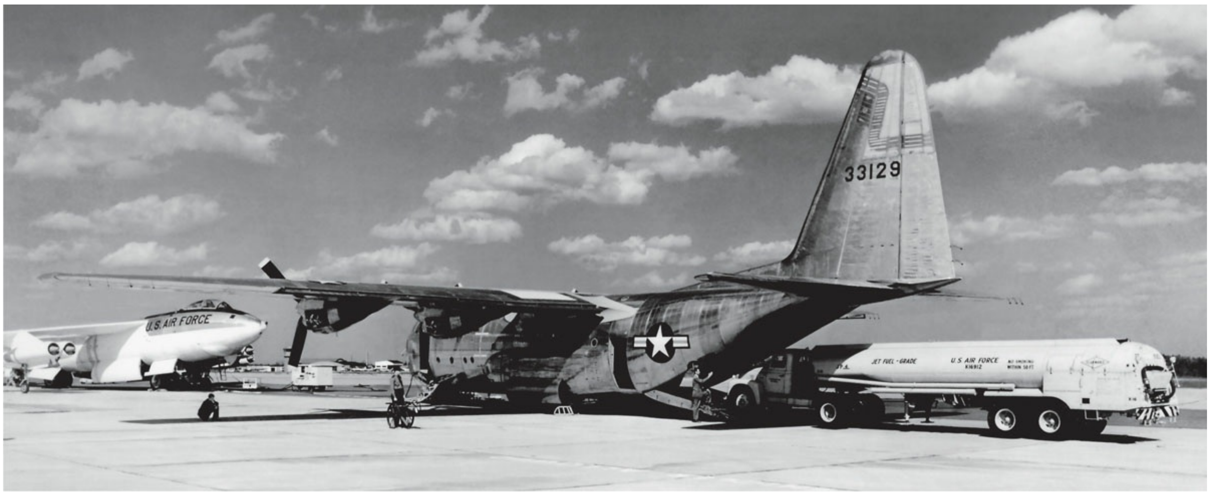
Both YC-130s take to the air as they fly over the lower Central Valley fields just north of Bakersfield in the fall of 1954. (Lockheed Martin)



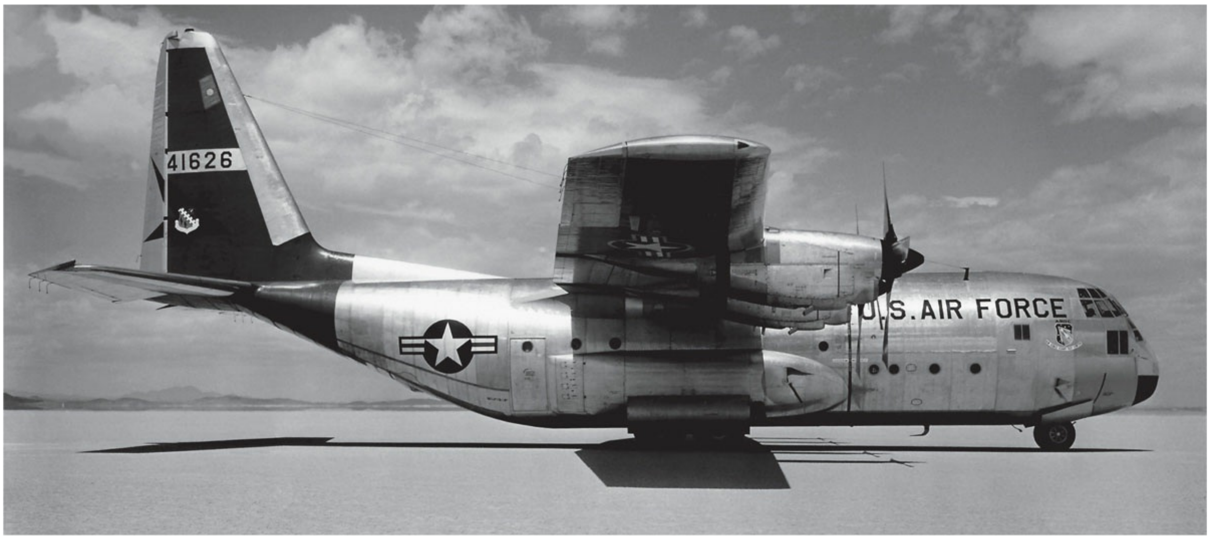
A YC-130 Hercules during its ferry flight from Burbank to Edwards AFB on 23 August 1954. (USAF)


UNITED STATES AIR FORCE

The YC-130 prototype on the ramp at Edwards AFB during early flight-testing and envelope expansion. (Lockheed Martin)


33129
U.S. AIR FORCE
JET FUEL - GRADE
U.S. AIR FORCE

C-130A 53-3129 is on the flight line at Edwards AFB while evaluating large cargo handling. Later in life, this C-130A was used as the prototype AC-130A Spectre gunship. (USAF)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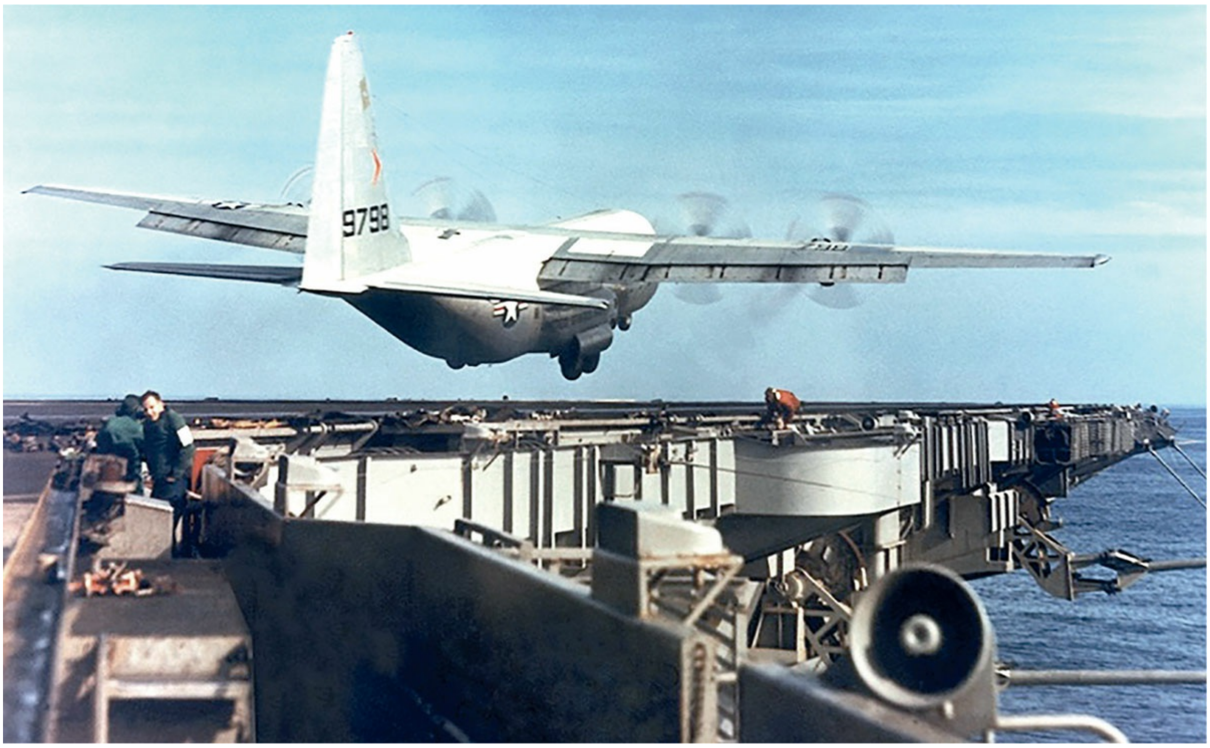
U.S. AIR FORCE

A sharp-looking AFFTC C-130A "Roman Nose" taxis to the runway during ongoing flight and envelope expansion. (USAF)

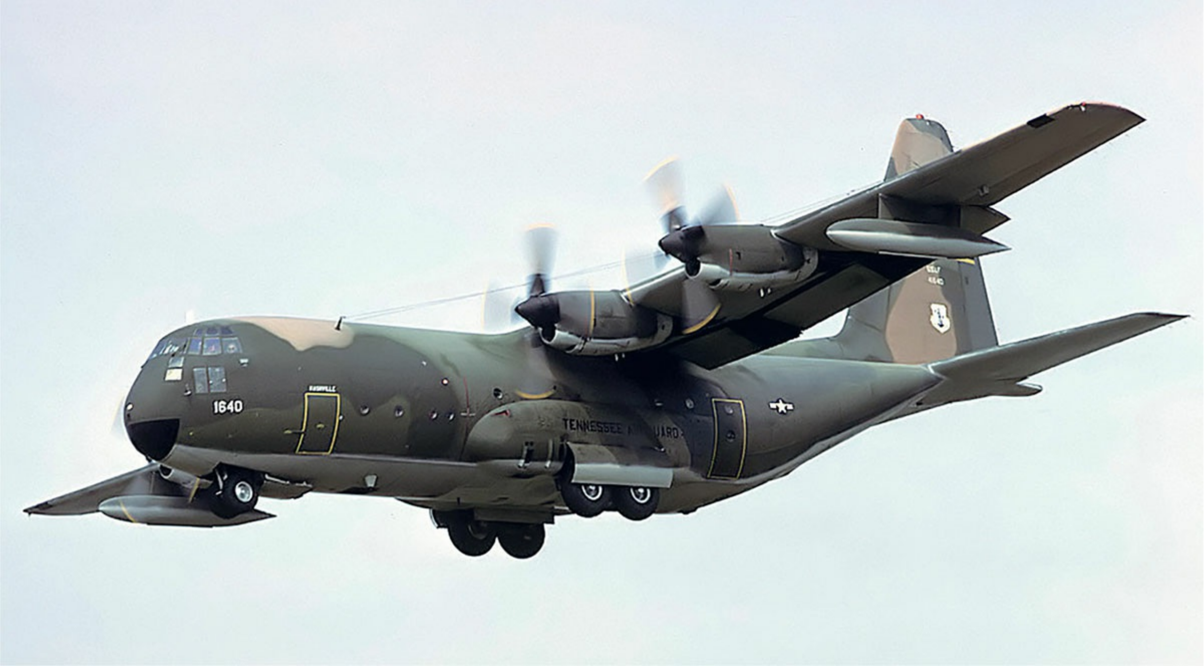
Two generations of military cargo transports, an early C-130A Hercules and a Fairchild C-119 Flying Boxcar on the taxiway at Edwards AFB. (USAF)

USAF C-130B was modified off the assembly line in Marietta, as a prototype for a Short Takeoff Vertical Landing (STOVL) transport for the US Army. (Lockheed

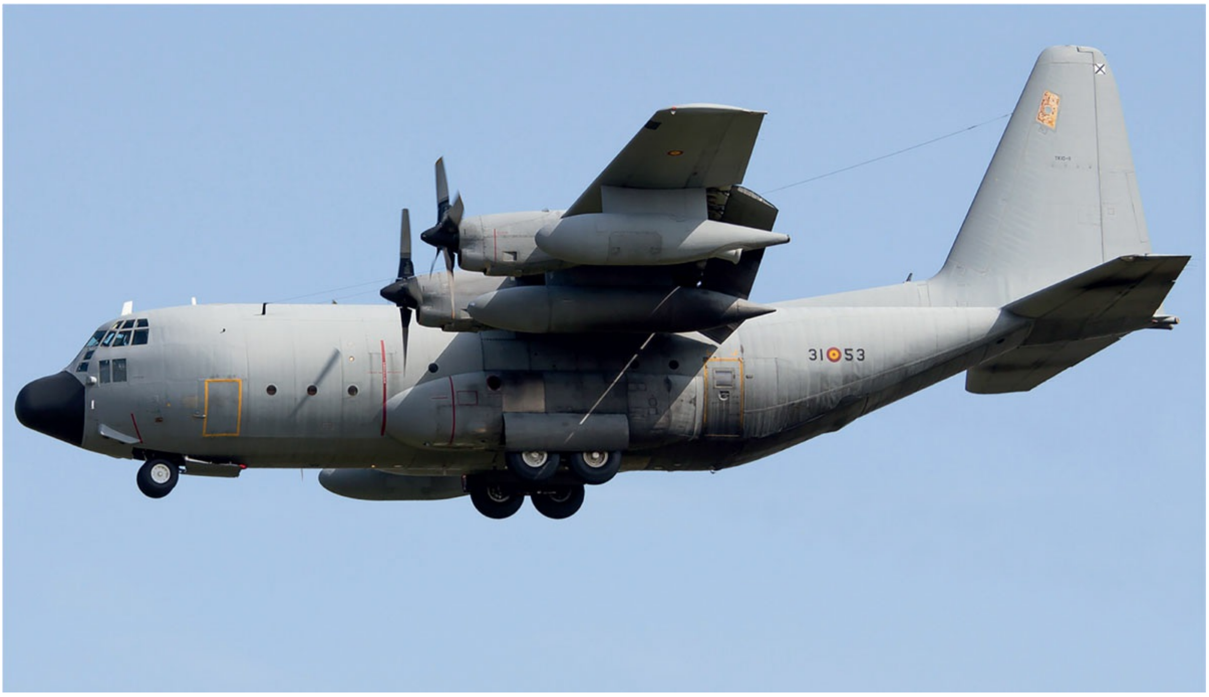
Martin)



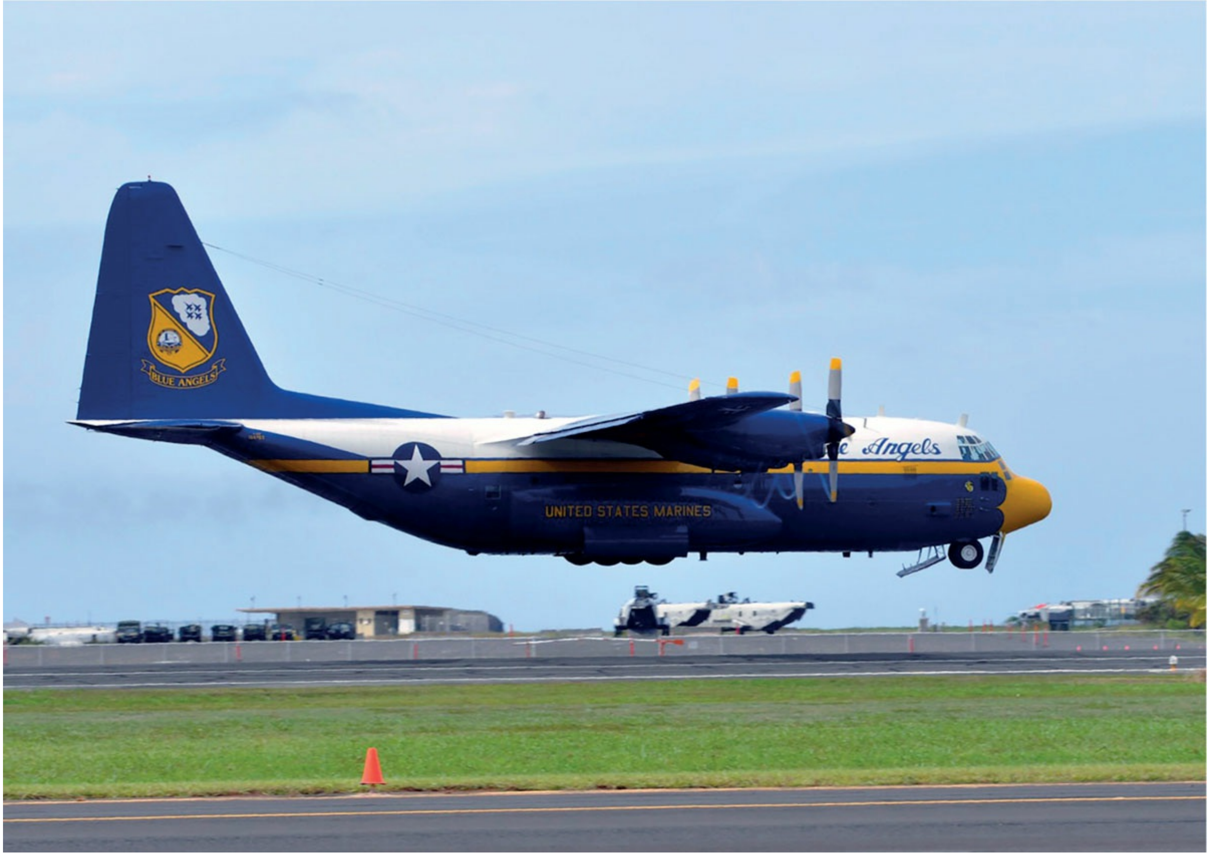
History was made on 30 October 1963 when a US Marine Corps KC-130F, BuNo 149798, landed and then took off from the USS *Forrestal* (CV-59). The tests were conducted 500 nautical miles off the coast of Massachusetts and the crew made a total of 29 touch-and-goes and 21 full-stop landings and takeoffs on 30 October, and on 8, 21 and 22 November 1963. (US Navy)



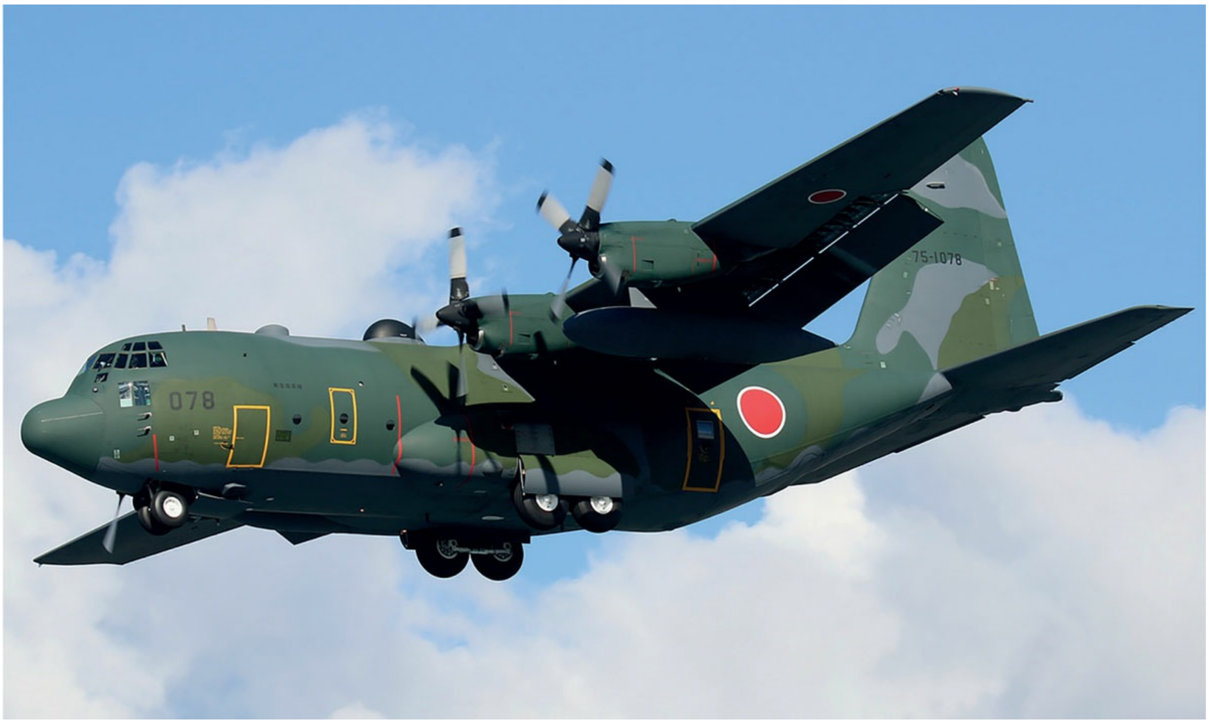
USAF ANG C-130A 54-1640 of the 105th Tactical Airlift Squadron from Nashville arriving for the International Air Tattoo 1979 on 20 June 1979 at Greenham Common, England. (Author's collection)



A Spanish KC-130H on approach to Gran Canaria, Spain, in mid-2017. (Author's collection)

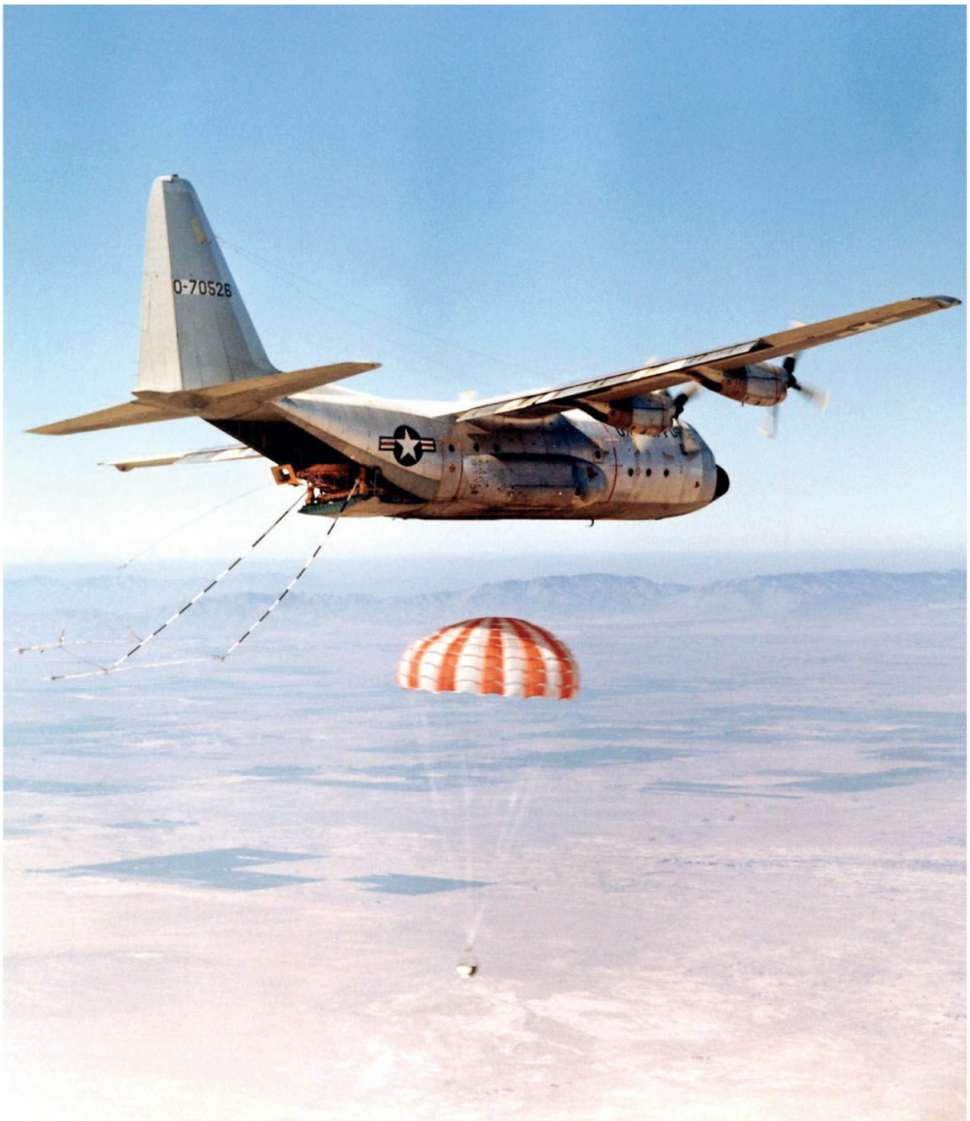

BLUE ANGELS
Angels
UNITED STATES MARINES

The C-130T called "Fat Albert" does a fly-by at Kaneohe Marine Corps Base during the Blue Angels demonstration on 28 September 2012. (James C. Goodall)

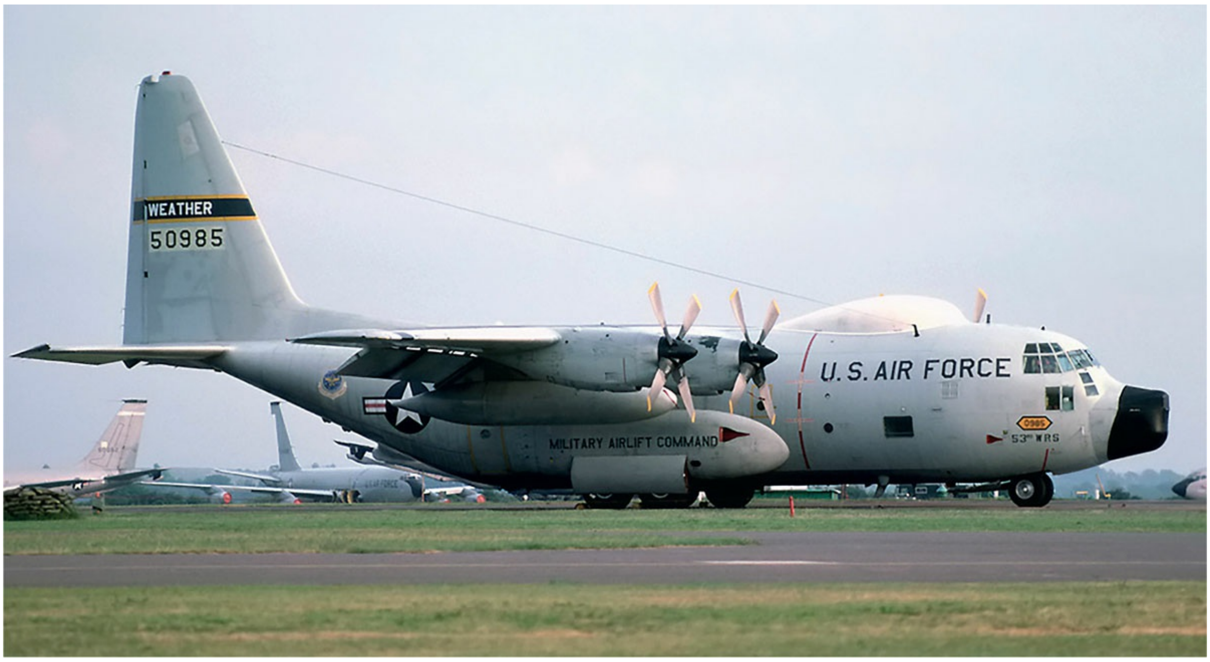


A Japan Maritime Self-Defense Force C-130R 75-1078 on approach to Atsugi Air Base, Japan. (Author's collection)

An MC-130H Combat Talon II lands on 16 March 2011 at Sendai Airport, Japan. This was the first fixed-wing aircraft to land at the airport after the earthquake and tsunami crippled much of the eastern seaboard on 11 March. (USAF)



A USAF JC-130B practices catching a satellite "Bucket" with grappling gear and winch over Edwards AFB in 1969. (USAF)


WEATHER
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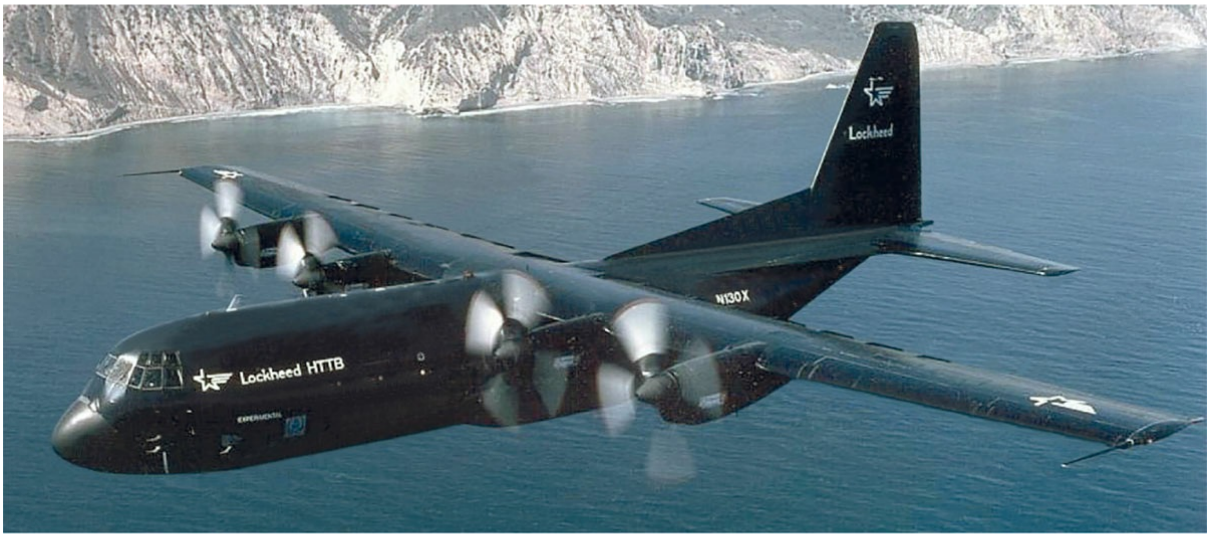
MILITARY AIRLIFT COMMAND
0985
53rd WRS

A USAF WC-130H 65-0985 from the 53rd Weather Reconnaissance Squadron is seen at RAF Mildenhall some time during July 1978. (Author's collection)


Lockheed
Lockheed HTTB
N130X
EXPERIMENTAL

This plane was a modified L-100, the commercial version of a C-130 Hercules Transport. It was built and owned by Lockheed Aeronautical Systems Company. The plane, developed in 1984, was the only one of its kind and was called a High Technology Test Bed, or HTTB. (Lockheed Martin)

XFV SALMON

1954

PROGRAM: XFV-1

Name: Salmon

Mission: Vertical takeoff and landing

Length: 36ft 10.25in (11.23m)

Wing Span: 30ft 10.1in (9.4m)

Height: 36ft 10.25in (11.23m)

Max T.O. Weight: 16,221lb (7,358kg)

First Flight: 16 June 1954

Last Flight: Program canceled June 1955

Crew: 1

Number Built: 1

Power Plant: 1 x Allison YT40-A-6 turboprop

Design Speed: Mach 0.76 (580mph; 930km/h)

Service Ceiling: 43,300ft (13,100m)

Combat Radius: N/A

Weapons Load: N/A

The US Navy had long held an interest in the vertical takeoff and landing (VTOL) aircraft. Both they and the USAF had issued VTOL study contracts as early as 1947, and in 1950 the Navy held a competition to produce a VTOL fighter with conventional flight performance, which could compete favorably with contemporary fighter aircraft.

The Lockheed XFV-1 was an experimental vertical takeoff aircraft of the 1950s. It was a result of a proposal issued by the Navy in 1948 for an aircraft capable of vertical takeoff and landing aboard platforms mounted on the afterdecks of conventional ships. In 1950, this requirement was revised to call for a research aircraft capable of eventually evolving into a VTOL ship-based convoy escort fighter. On 19 April 1951, two prototypes were ordered from Lockheed under the designation XFO-1.

Work on the project began in August 1951. Soon after the contract award, the designation was changed to XFV-1. The XFV-1 sat on its tail for landings and takeoffs. It had a short and squat fuselage with tapered broad-chord short-span wings with pods at the extreme tips. The aircraft sat on the runway in the vertical position, resting on equal-span cruciform tail surfaces, each having a fully castoring strut and wheel at their tip. At takeoff, the engine ran up to full power and the aircraft ascended vertically, then when it reached a safe altitude it gradually nosed over into conventional horizontal flight. At landing, the aircraft approached the landing pad while pitched up into a nose-high position and then descended to the ground under gradually reduced power.

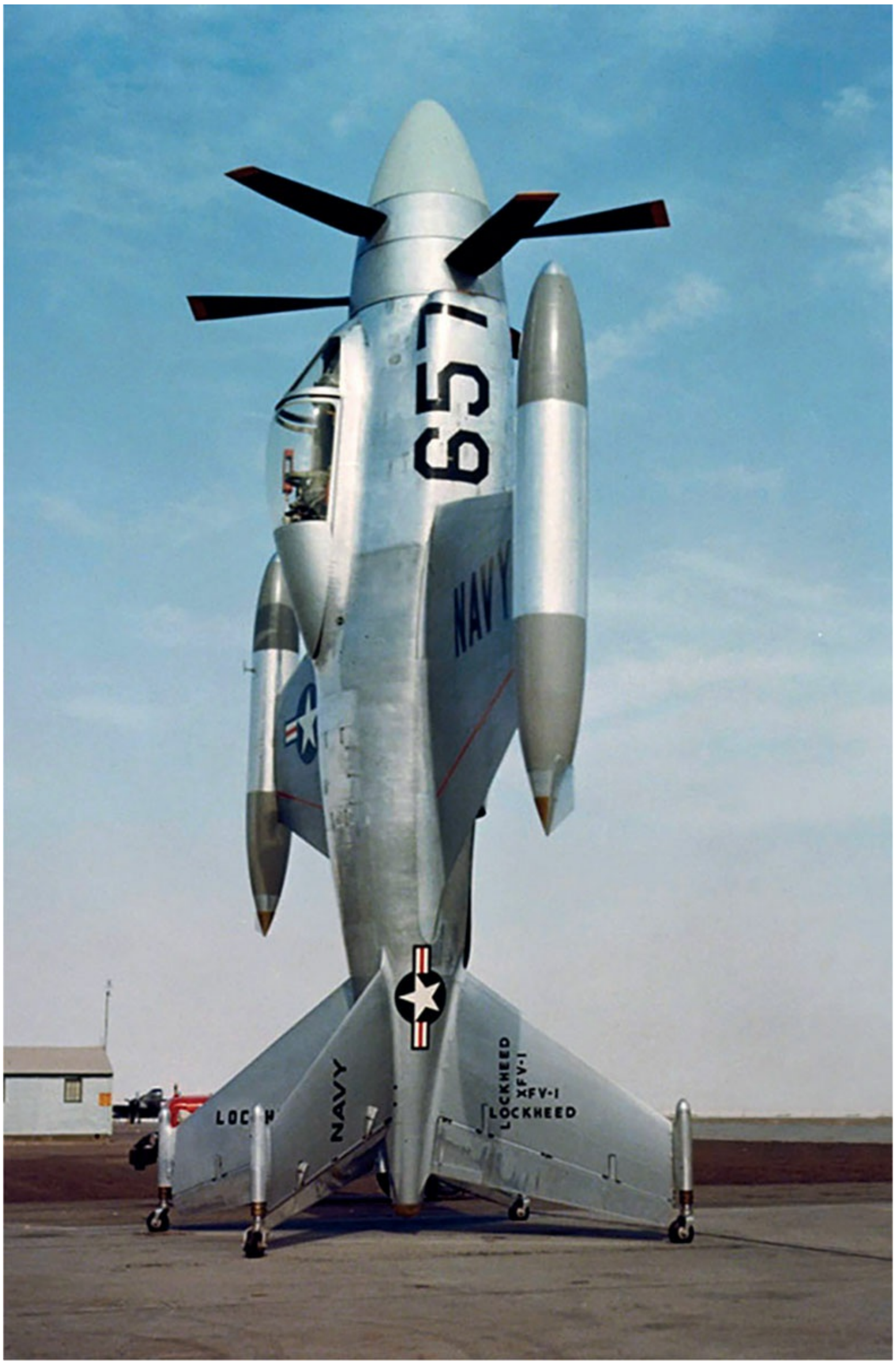
The XFV-1 was powered by an Allison YT40-A-6 turboprop (which consisted of a pair of coupled T38 turbines) driving a pair of three-bladed contra-rotating propellers in the nose. The engine offered a power of 5,500shp. The air intakes for the engines were on the edges of the forward fuselage, and the exhaust was on the bottom of the rear fuselage.

The single pilot sat underneath a cockpit canopy which slid toward the rear. Entry to or exit from the cockpit required a special ladder, and by all accounts was rather awkward. The first prototype (Build Number [BuNo] 138657) was ready by late 1953. Since the YT40-A-6 engine was deemed not sufficiently powerful for sustained vertical flight, the aircraft was flown in conventional horizontal mode. For this, a temporary non-retractable undercarriage, with long braced V legs was attached to the fuselage, and fixed tailwheels were attached to the lower pair of fins. In this form, the aircraft was trucked out to Edwards Air Force Base, California, in November of 1953 for ground testing and taxiing trials. During one of these tests, at a time when the aft section of the large spinner had not yet been fitted, test pilot Herman "Fish" Salmon managed to taxi the aircraft past the liftoff speed, and the aircraft made a brief hop on 23 December 1953. It would be several months before the engine was ready for the first official flight, which finally took place on 16 June 1954.

Full VTOL testing awaited the availability of the 7,100shp YT40-A-14. Unfortunately, this engine never materialized, and the XFV-1 never actually made any vertical takeoffs or landings. However, it did make a few transitions in flight from the conventional to the vertical flight mode and back, and had briefly held in hover at altitude. All flights at Edwards AFB were made with the lightweight spindly undercarriage.

The proposed production version was designated FV-2 (Model 181-43-02). It was to have been powered by the T54-A-16 turboprop, and to have had a bullet-proof windshield, armor, and radar in the fixed forward part of the nose spinner. The proposed armament was four 20mm cannon fitted in the two wingtip pods. Alternatively, 48 2.75in folding-fin rockets could be fitted.

Despite making a total of 32 flights, briefly holding a hover at altitude, and managing a few transitions in flight from the conventional to the vertical flight mode and back again, the project was doomed to be canceled in June 1955. The XFV-1 had not made a single vertical takeoff or landing, and only the most experienced pilots were able to fly the aircraft. The final straw was the Navy's realization that even if the XFV-1 had been able to take off vertically, its speed would never have matched those reached contemporary fighters.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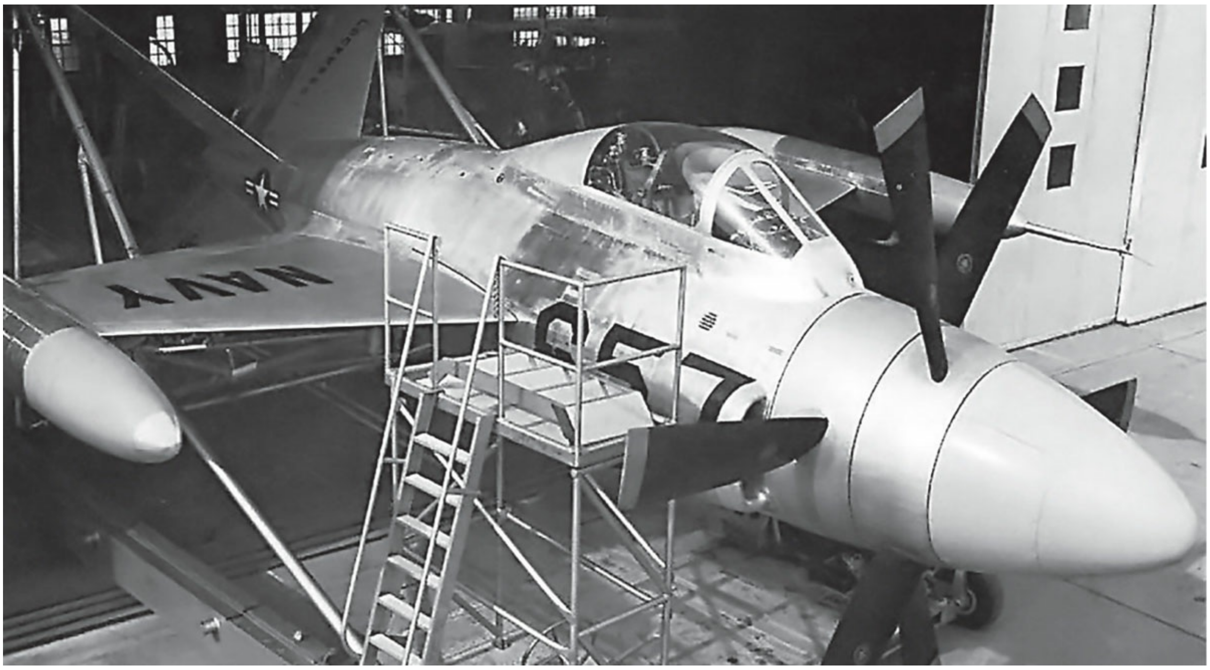
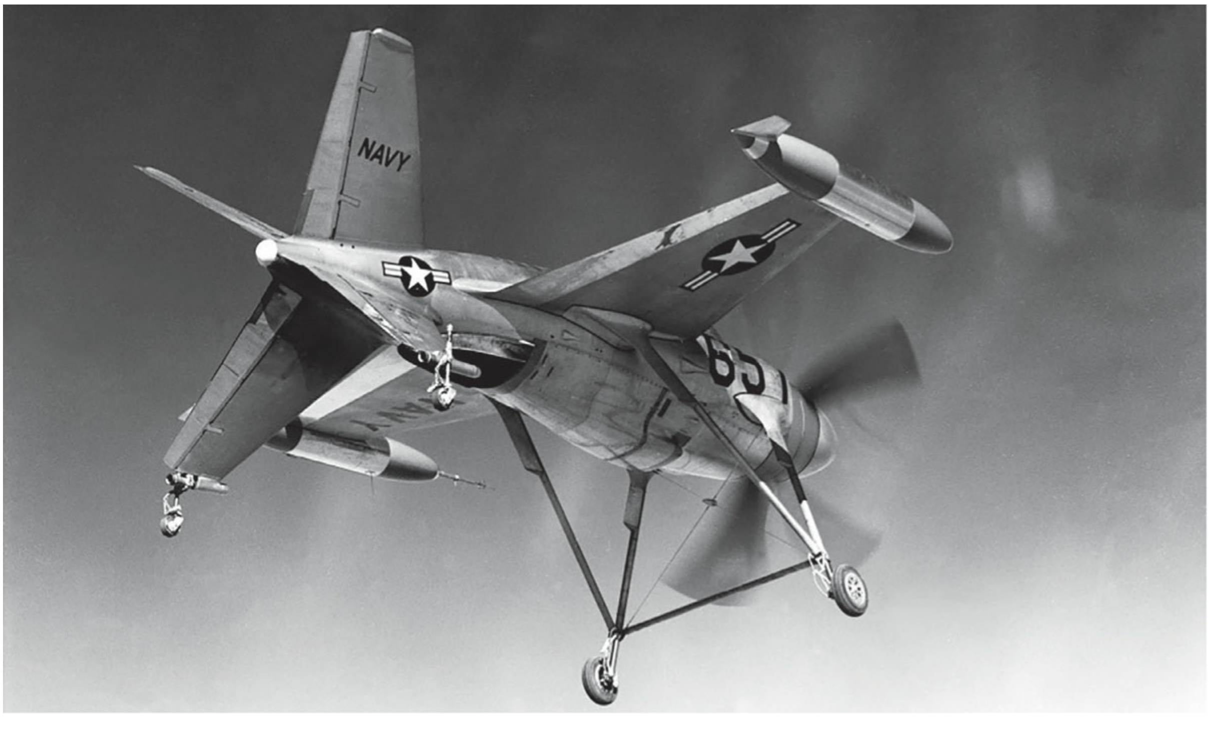
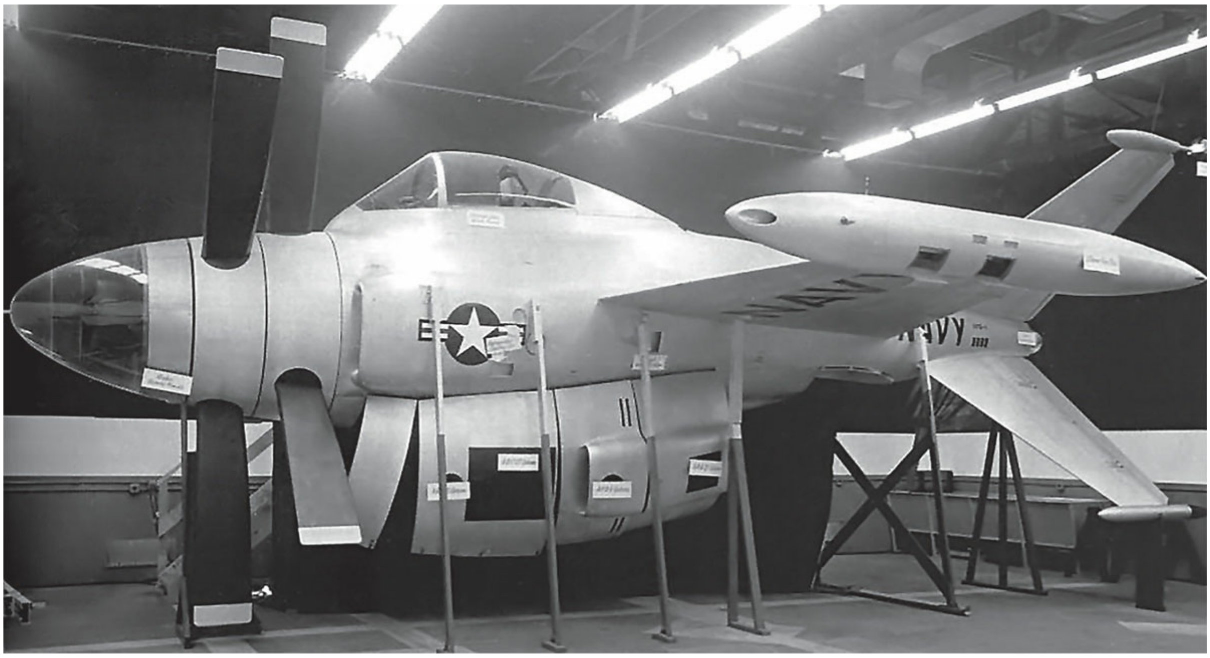
A beautiful color shot of the XFV-1 Salmon US Navy vertical takeoff and landing prototype. (Lockheed Martin)



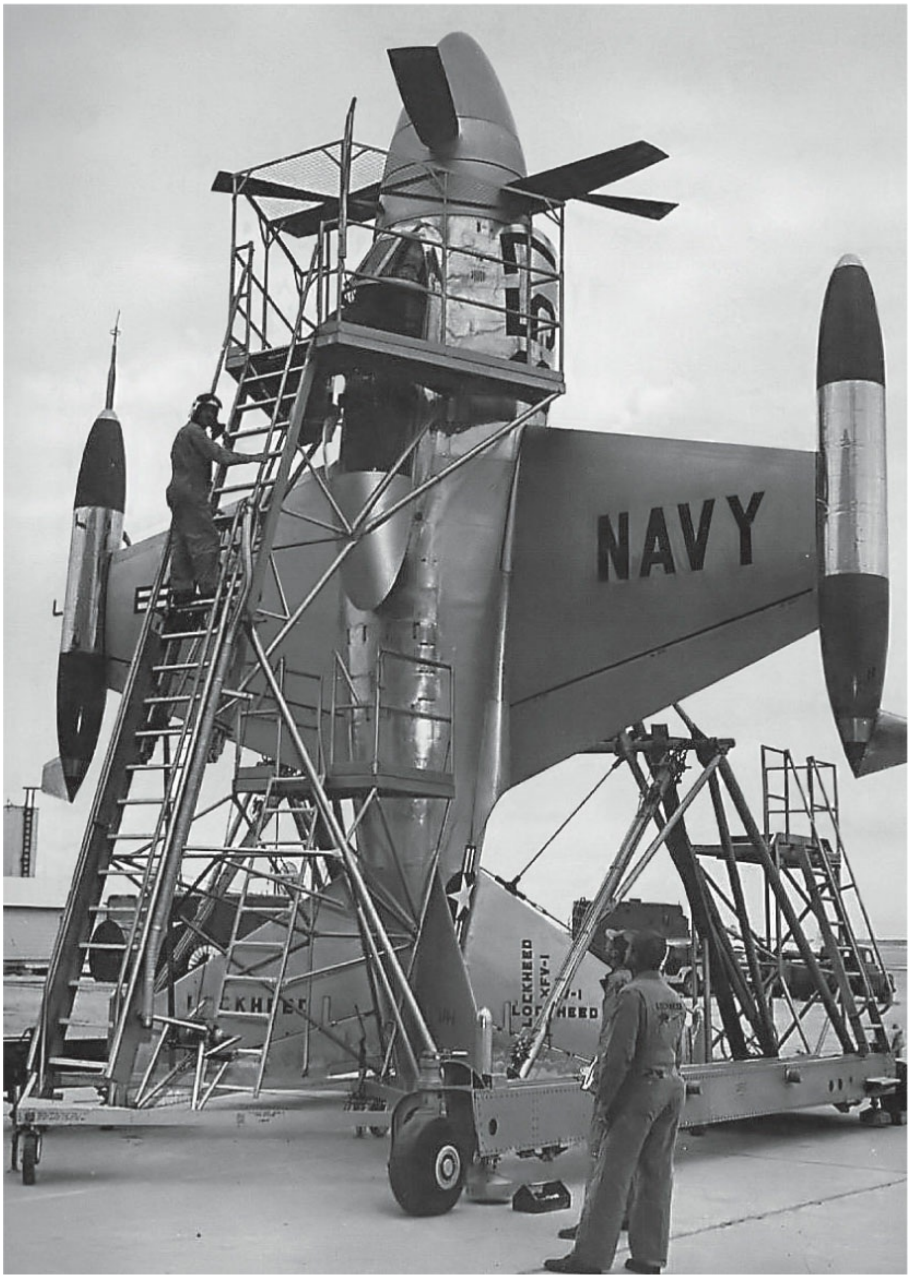
The proposed production version was to have been powered by the T54-A-16 turboprop, incorporating a bullet-proof windshield, armor and radar in the fixed forward part of the nose spinner. (Author's collection)



A rear view of the XFV-1 Salmon in flight with its horizontal land fixture in place as the Allison YT-40-A-14 turboprop was not ready for installation and the XFV-1 had to rely on a less powerful YT-40-A-6. (Lockheed Martin)

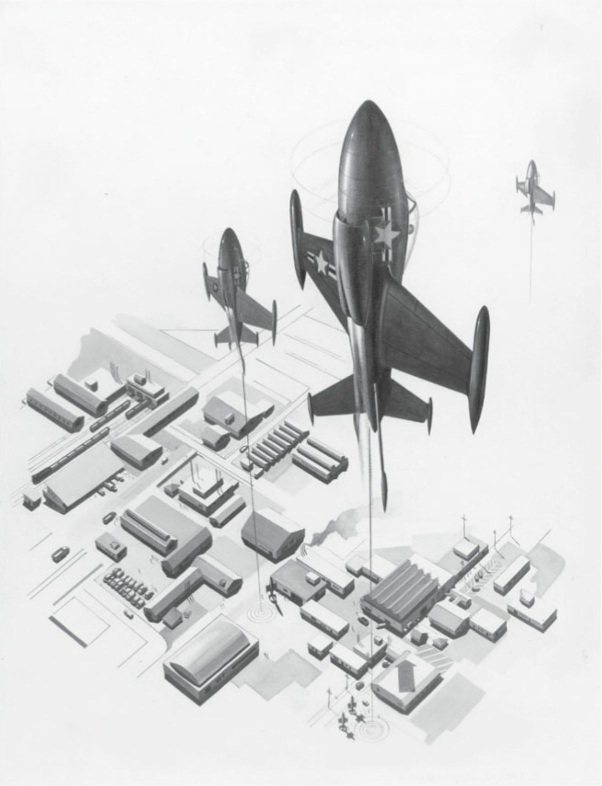


On 19 April 1951, two prototypes were ordered from Lockheed under the designation XFO-1. Soon after the contract was awarded, the project designation changed to XFV-1 when the Navy's code for Lockheed was changed from O to V. (Author's collection)



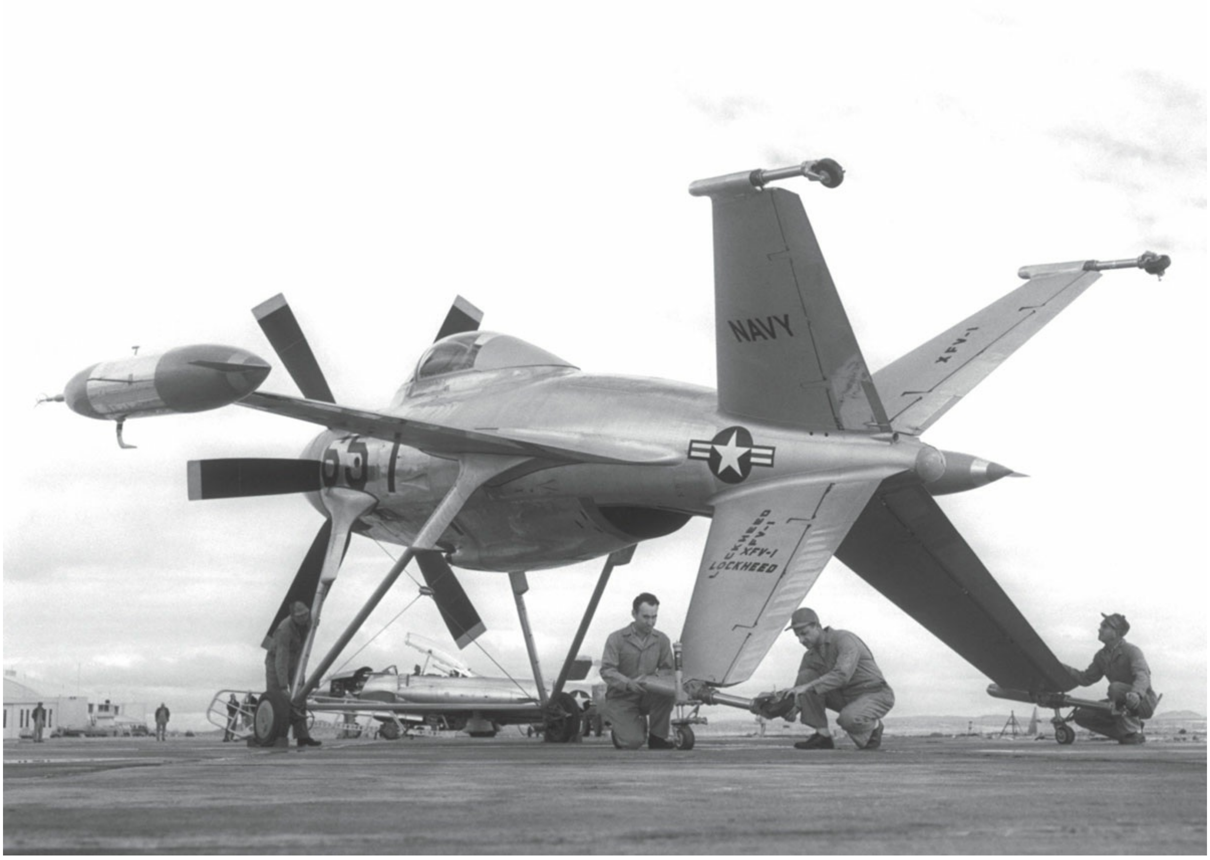
This image shows the complex amount of gear needed to support the XFV-1. This would have been a nightmare on the limited space of a surface combat ship, and the support equipment would have been an equal challenge on board a rolling ship during heavy seas. (Author's collection)

Lockheed test pilot Herman "Fish" Salmon looks over his shoulder and smiles for the camera during a photo shoot prior to first flight. (Lockheed Martin)



An artist's drawing depicting a cartoon version of the XFV-1 taking to the air.

(Lockheed Martin)


NAVY
XFV-1
63 | 1
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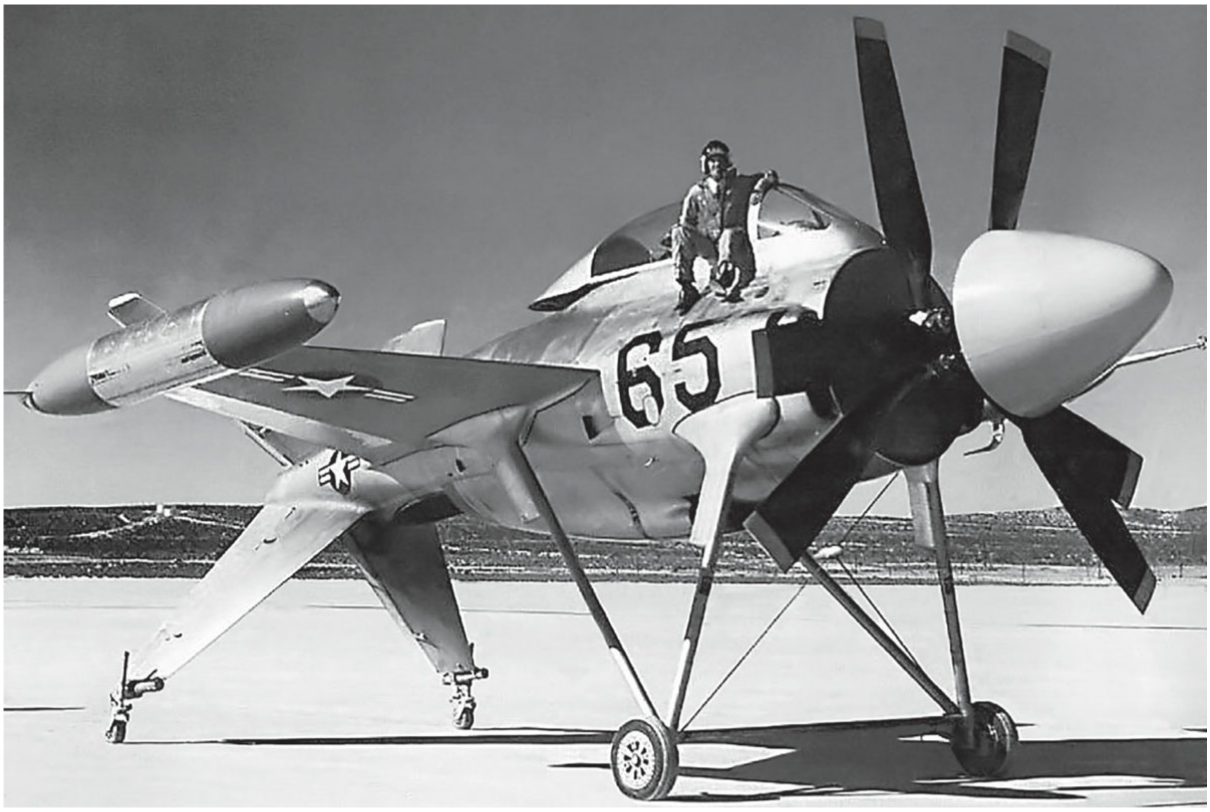
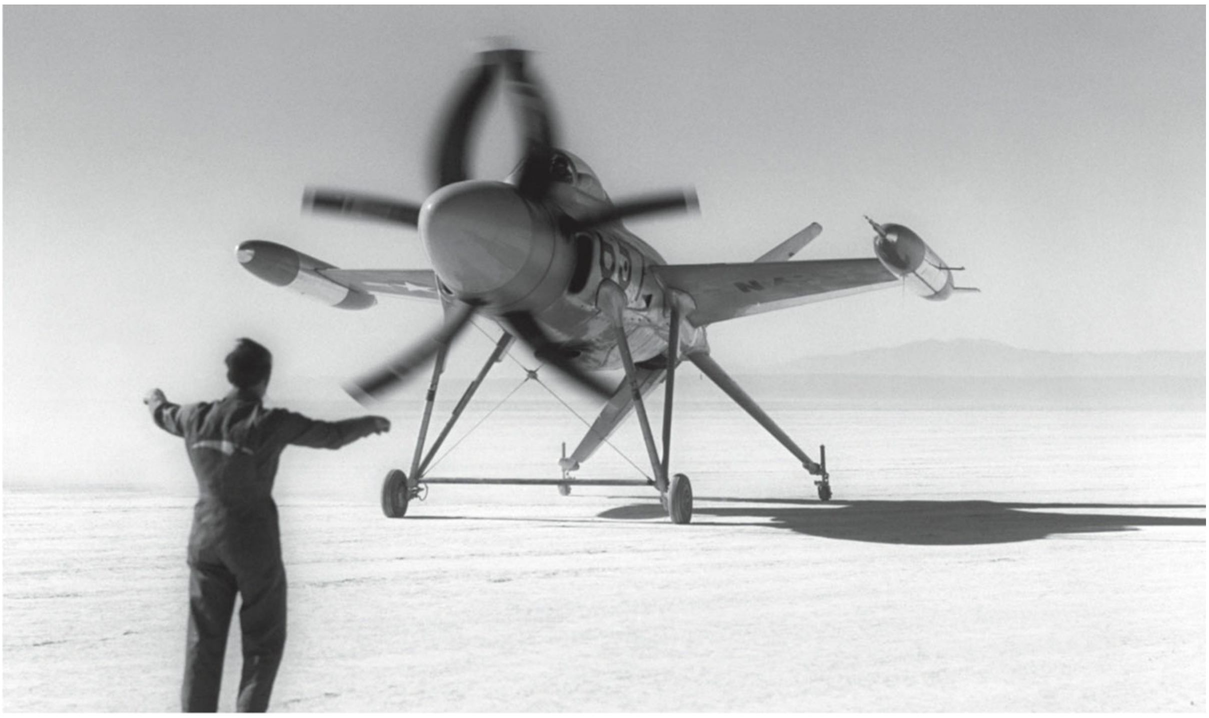
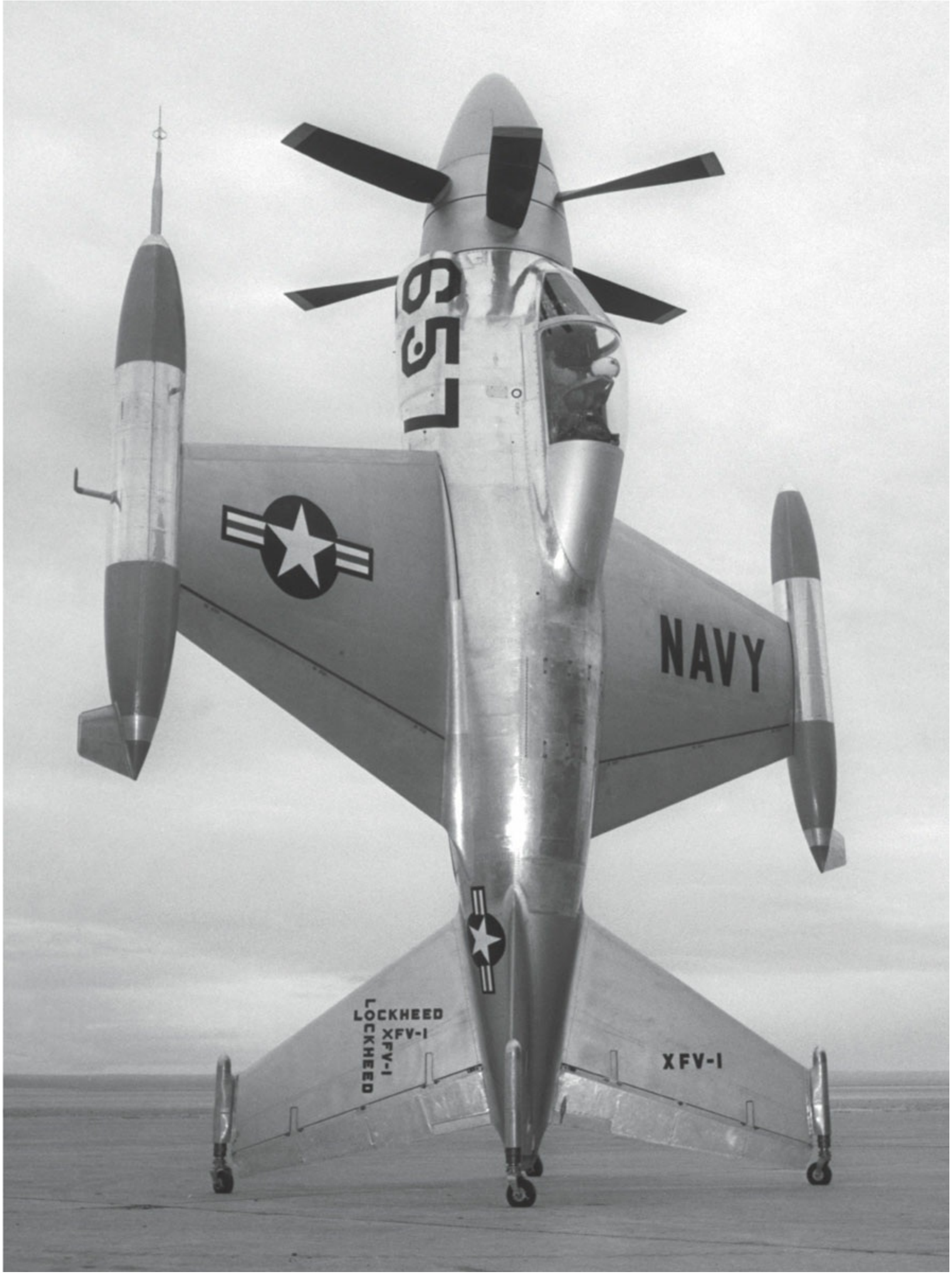
A closeup photo taken of the rear end of the XVF-1 Salmon as it is being gone over after a high-speed taxi test in the fall of 1954. (Lockheed Martin)



XFV-1 pilot Herman "Fish" Salmon sits on the edge of the cockpit after a high-speed taxi test in 1953. (Lockheed Martin)



The XFV-1 during an early taxi test in the fall of 1953. (Lockheed Martin)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NAVY
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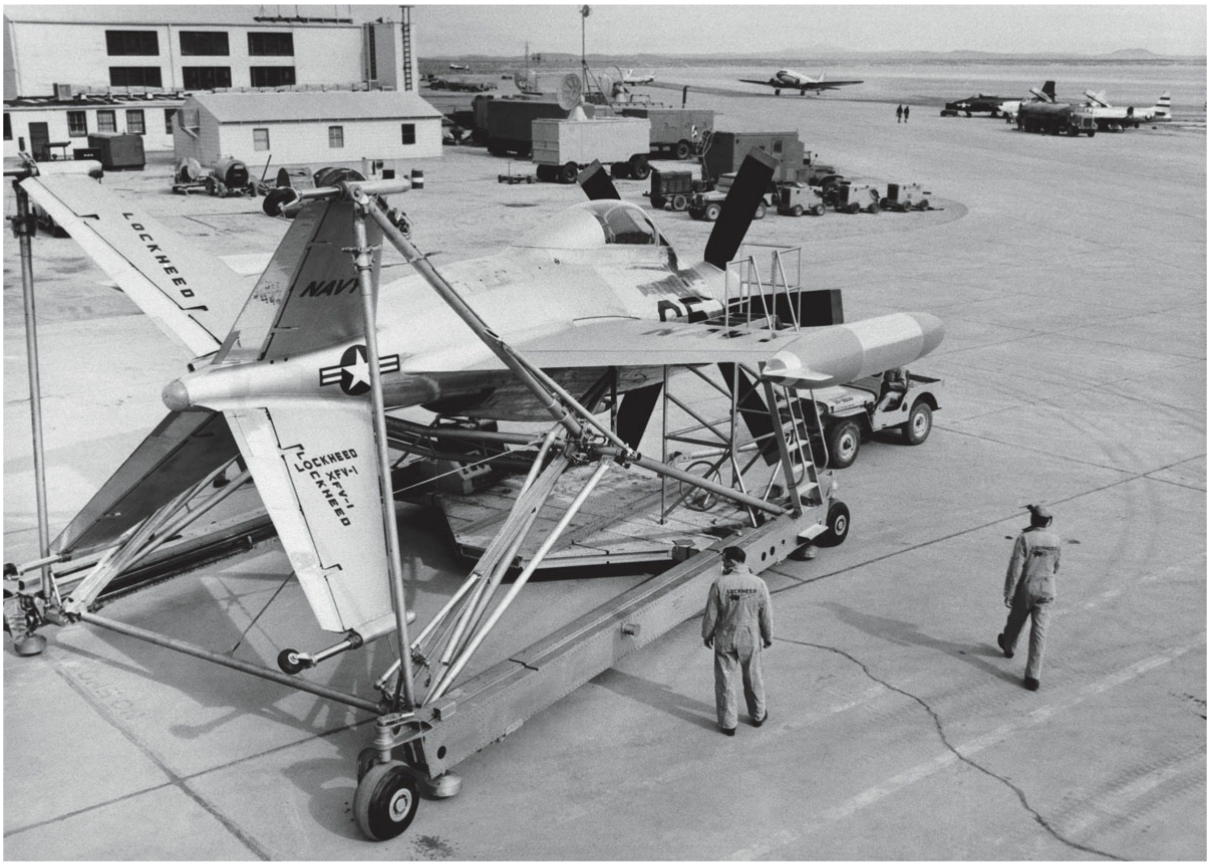
XFV-1

A view of the XFV-1 with Herman "Fish" Salmon in the cockpit in this early 1953 photo. (Lockheed Martin)


LOCKHEED
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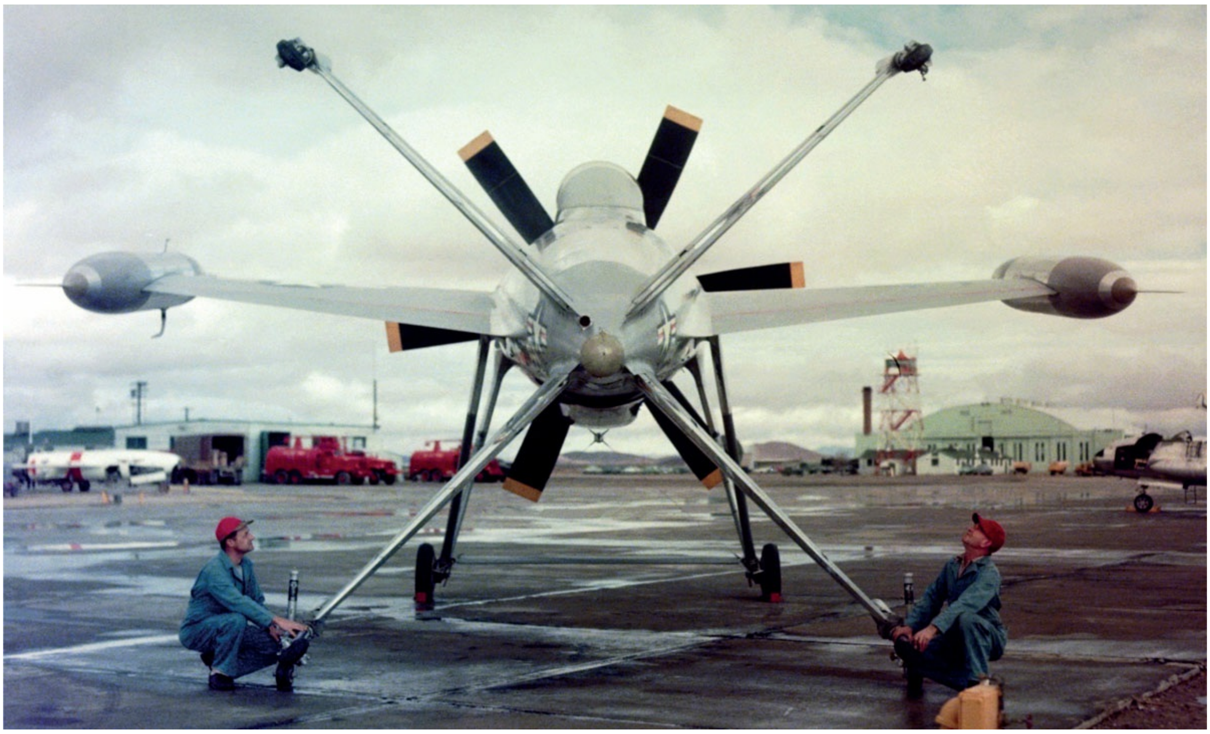
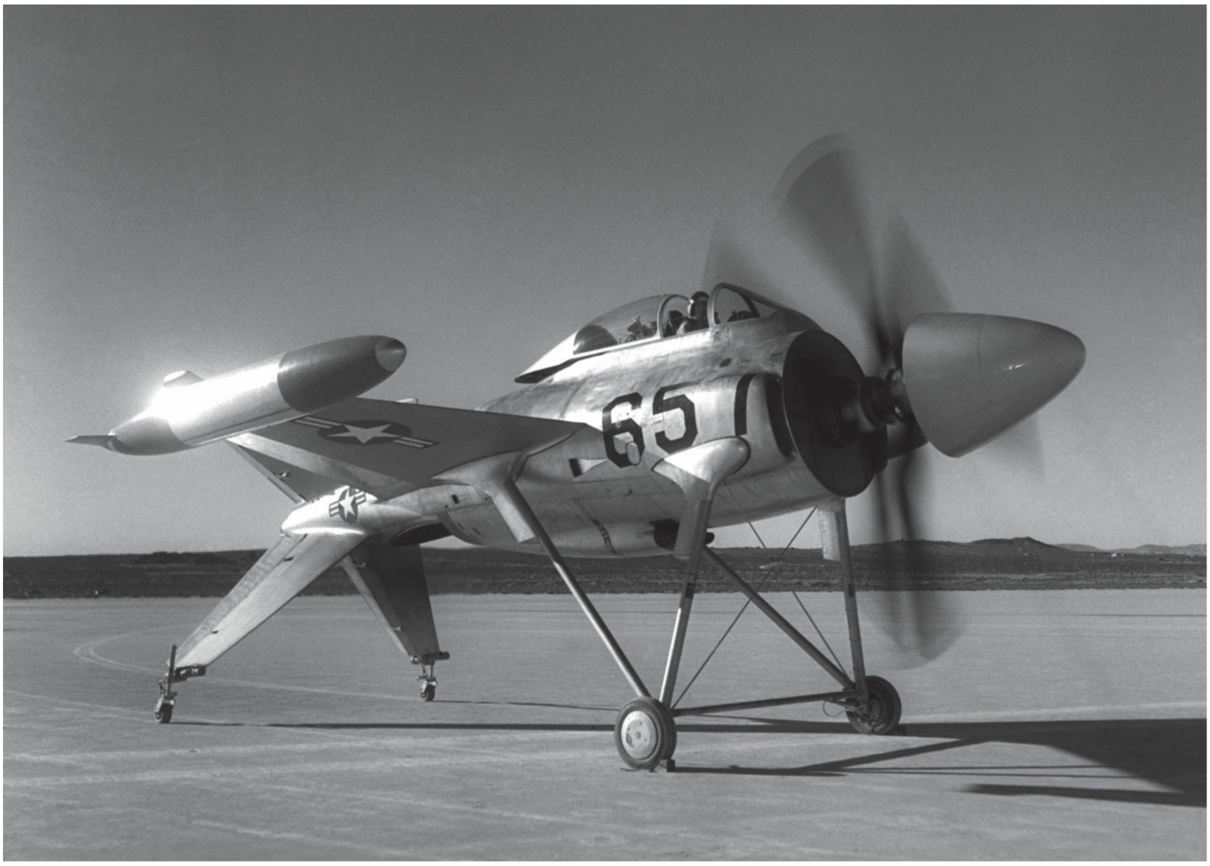
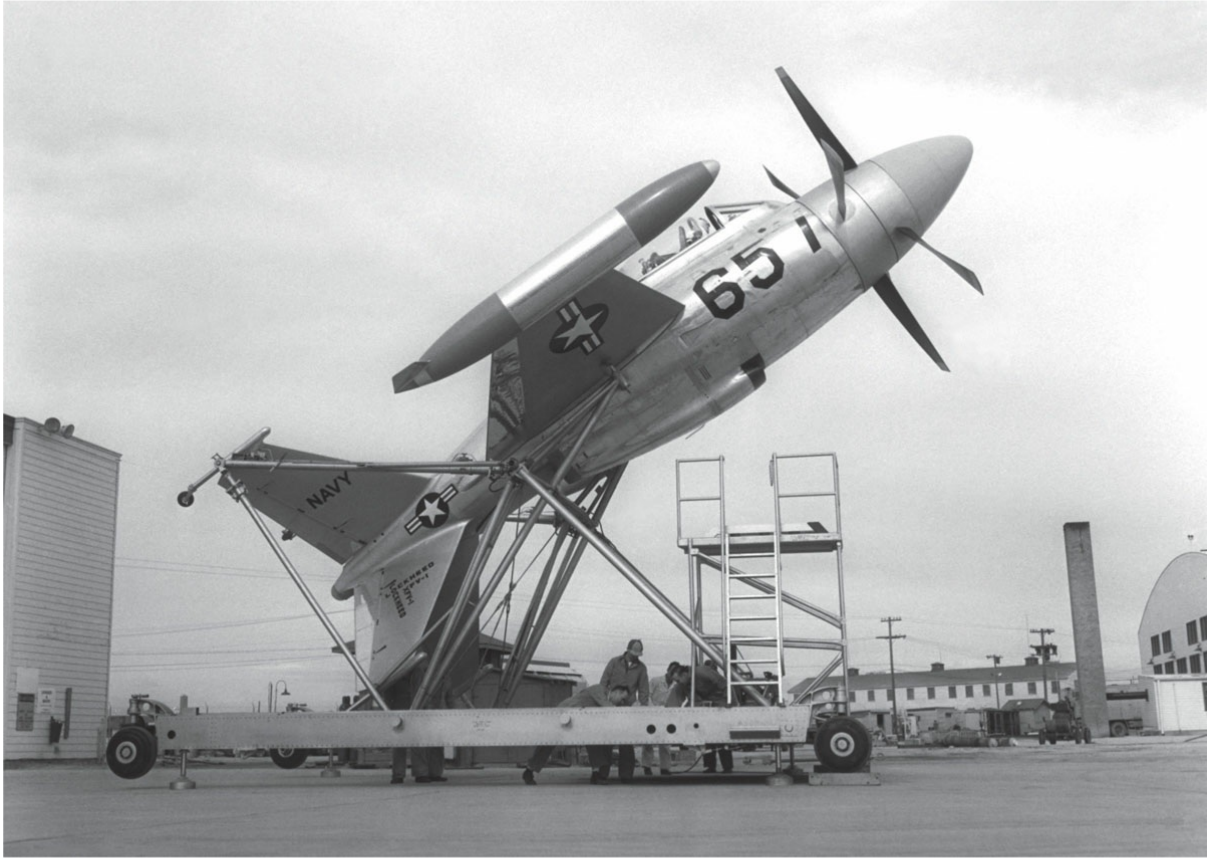
It is this type of handling equipment that would have made the XFV-1 an operational nightmare considering the limited space on a troop transport ship. (Author's collection)



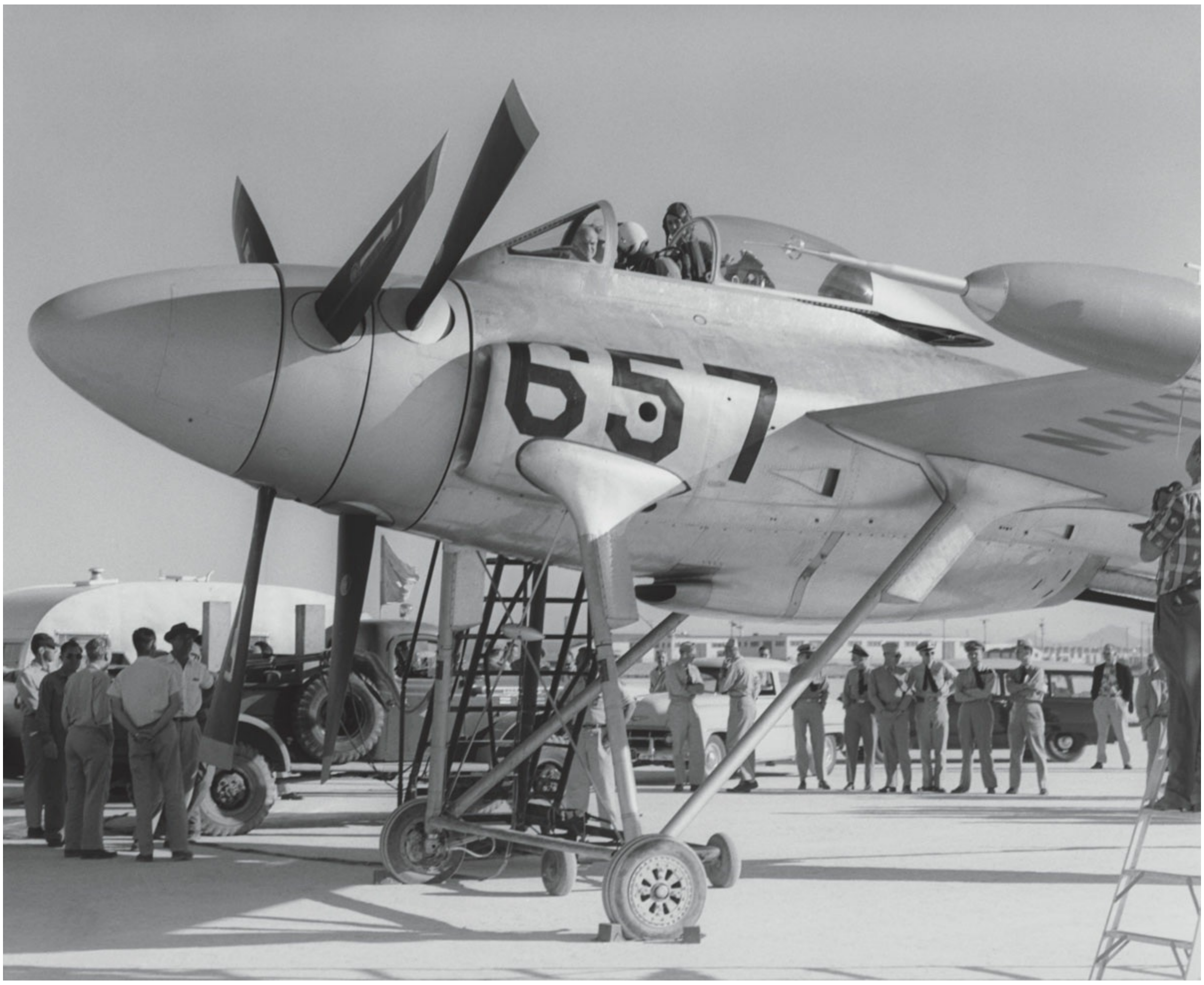
Another closeup photo taken of the rear end of the XVF-1 Salmon as it is being checked over after a high-speed taxi test in the fall of 1954. (Lockheed Martin)



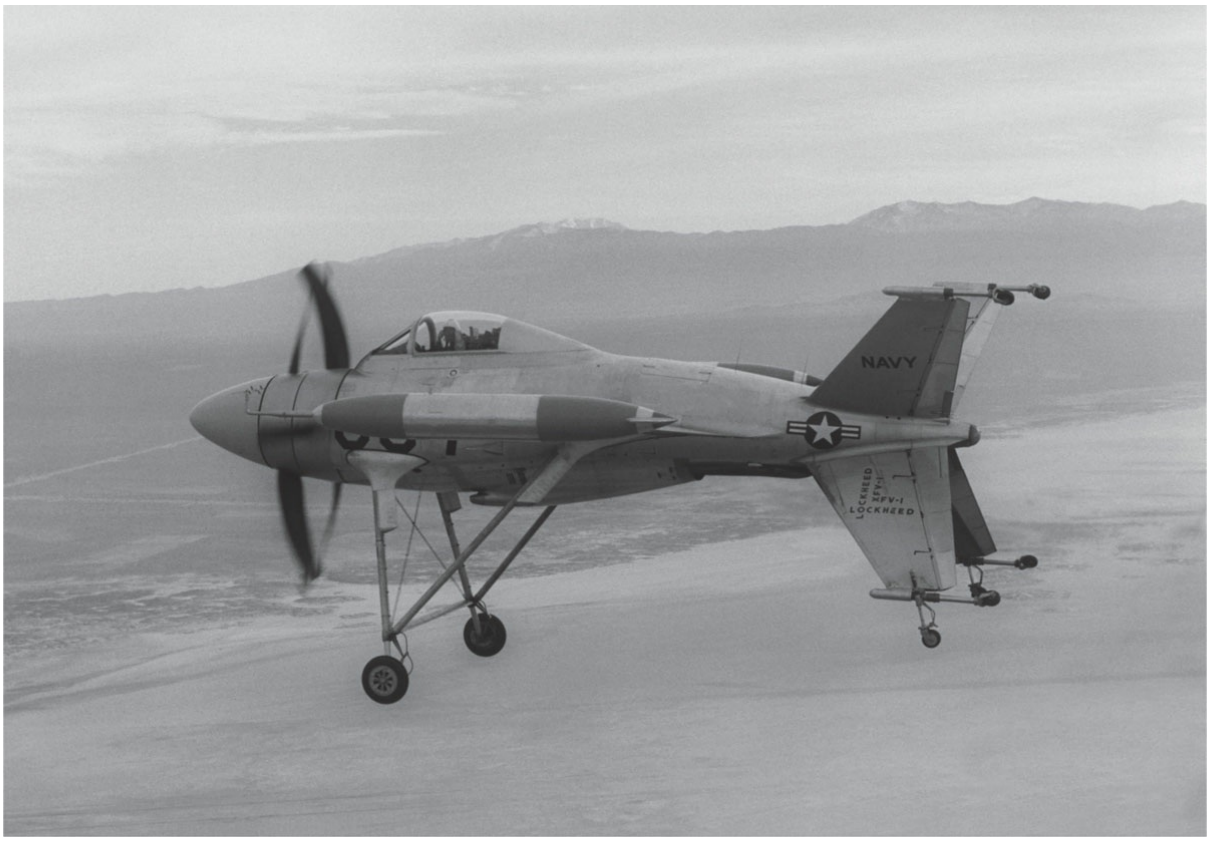
High-speed taxi test with drag-limiting horizontal landing gear. (Author’s collection)



This photo taken in March 1954 shows off the specialized trailer that was needed for erecting the XVF-1 for vertical flight, which is shown in the lift position. (Lockheed Martin)



With Herman Salmon in the cockpit, a crowd of onlookers watches as "Fish" starts the engine in this 1954 photo. (Lockheed Martin)


NAVY
LOCKHEED
XFV-1
LOCKHEED

Drag generated by the temporary landing gear adversely affected the maximum speed of the XFV-1. The aircraft never flew without the temporary landing gear. (Lockheed Martin)

XF-104 STARFIGHTER

1954

PROGRAM: XF- 104

Name: Starfighter

Mission: Interceptor

Length: 54ft 8in (16.66m)

Wing Span: 21ft 9in (6.63m)

Height: 13ft 6in (4.11m)

Max T.O. Weight: 29,027lb (13,166kg)

First Flight: 4 March 1954

Last Flight: 31 October 2004 (Italian Air Force)

Crew: 1 pilot; 2 in the TF-104G and F-104D

Number Built: 2 XF-104s; 2,578 (of all types)

Power Plant: 1 x General Electric J79-GE-19

Design Speed: Mach 1.99 (1,528mph; 2,459km/h)

Service Ceiling: 50,000ft (15,000m)

Combat Radius: 420 miles (365nm; 676km)

Weapons Load: 7 hard points for a total of 4,000lb (1,800kg) weapons

In December 1951, after Lockheed Corporation aircraft designer Clarence "Kelly" Johnson returned from meetings with USAF pilots fighting over Korea, he was committed to developing the world's fastest and highest-flying fighter. Lockheed approved his team's design on 31 October 1952. The Air Force ordered two prototypes for testing on 1 March 1953.

The design was a product of the Korean War, and was unique in several respects. The encounters with the MiG-15 in Korea caused a strong outcry among Air Force fighter pilots for a cheap, lightweight, maneuverable, high-performance fighter to confront future Soviet fighters. The result was the F-104, a fighter that overemphasized rate of climb and brute speed. Intended as a point defense interceptor, range was sacrificed for rate of climb. Range, however, could be extended using external tanks and in-flight refueling. The F-104 had an exceptionally small wing span of only 21ft, and provided low-speed lift through air bled from the engine and vented over the wing. Designed as a supersonic superiority fighter, the F-104 was produced in two major versions. Armed with a six-barrel M-61 20mm Vulcan cannon it served as a tactical fighter and, equipped additionally with heat-seeking Sidewinder missiles, as a day/night interceptor. The USAF procured about 300 Starfighters in one- and two-seat versions.

The first XF-104 prototype flew one year later. It was noteworthy for its short, wide wing with a super-thin leading edge only 0.016in thick. The prototypes underwent a series of modifications to solve landing gear and stability problems that arose during testing. However, production awaited installation of the design's intended General Electric J79 afterburning turbojet engines. The resulting YF-104 became the basis for the F-104A that entered service in 1958, achieving several speed, climb-rate and operational flight records.

The YF-104A was the first aircraft to fly at twice the speed of sound and held numerous airspeed and altitude records. On 18 May 1958, an F-104A set a world speed record of 1,404.19mph, and on 14 December 1959 an F-104C set a world altitude record of 103,395ft. The Starfighter was the first aircraft to hold simultaneous official world records for speed, altitude and time-to-climb. Using an accelerated loft technique, some F-104s have been flown to higher than 90,000ft.

The new jet-powered, post-war design was not without its issues however, and four years of development for the program would follow. At least 17 pre-production YF-104A aircraft were generated for the USAF to fulfill testing roles of the various problematic systems aboard the F-104 and iron out some issues before production would commence. By 1958, the first F-104As were made available for deliveries. These systems differed somewhat from their original design in that they sported a longer fuselage and were fitted with their General Electric J79-GE-3 series engines which provided 14,800lb of thrust.

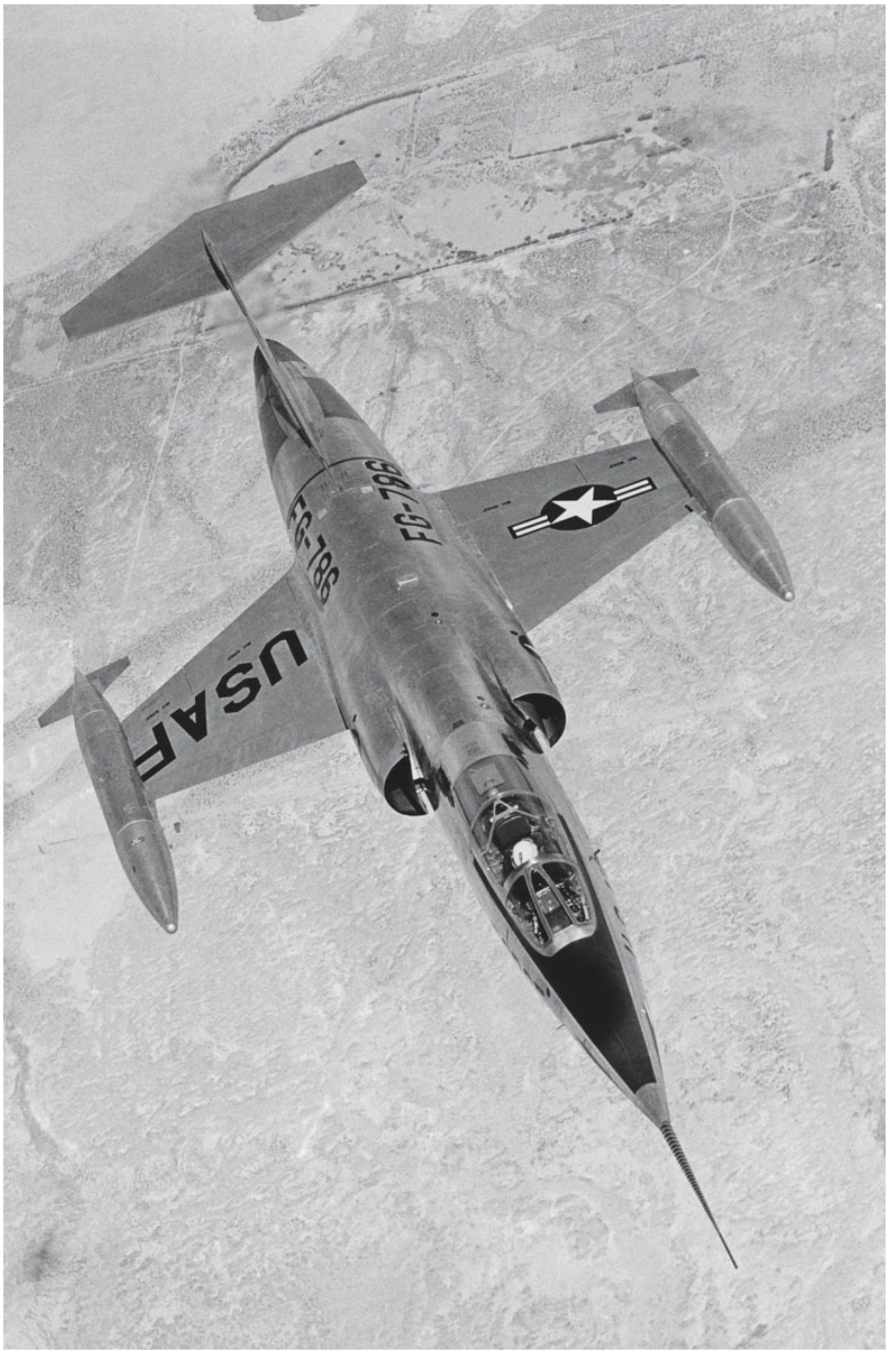
Often called “the rocket with a man in it,” the F-104 was the first operational aircraft to sustain Mach 2 speed in flight. It suffered from short range, obsolete avionics, high landing speed and, until late 1967, an unreliable engine.

The F-104 was selected for use by the NATO allies. More than 1,700 F-104s were built in the United States and abroad under the military aid program for various nations including Canada, West Germany, Italy, Norway, the Netherlands, Belgium, Denmark, Greece, Turkey, Spain, Taiwan and Japan. All F-104s were retired several years ago. Some F-104s had been modified to include a second cockpit for transition training and some weapons delivery. A reconnaissance version also exists although it never served with the USAF.

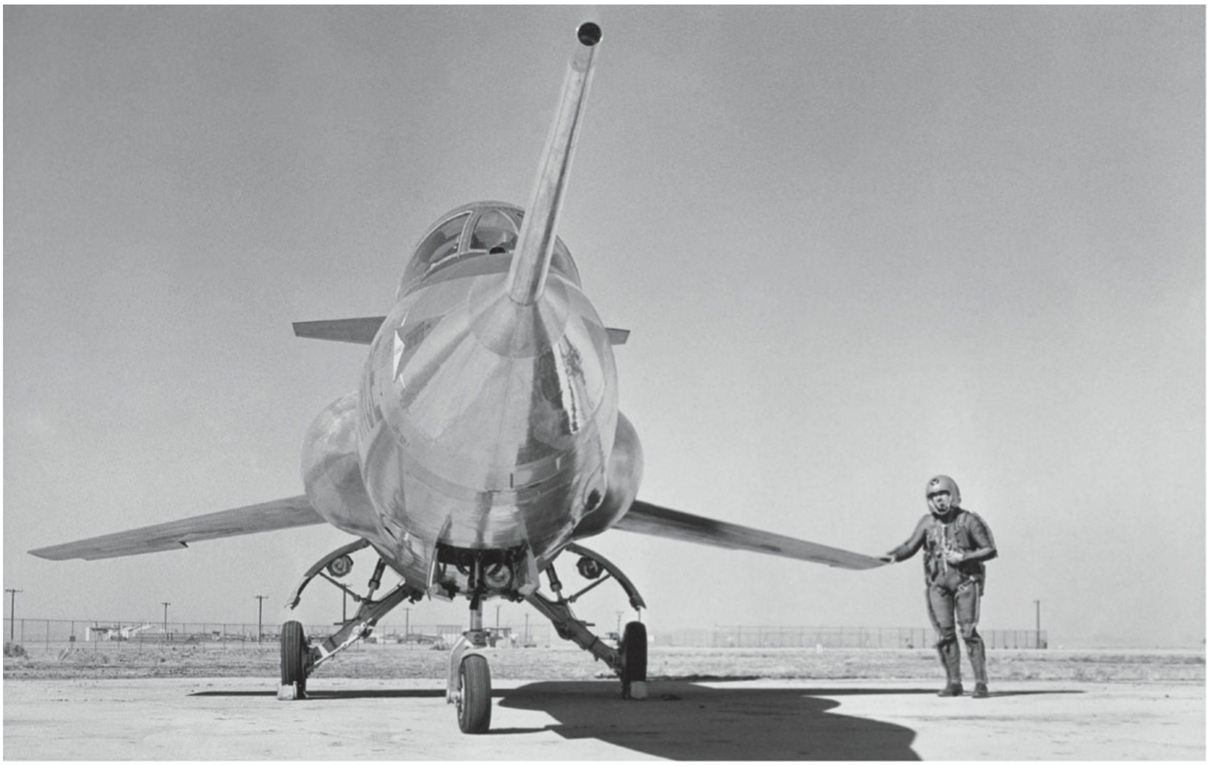
Externally, the F-104 Starfighter was really a distinct aircraft design. The platform showcased an aerodynamic streamlined fuselage design that held all of the vital components, weapons, avionics, undercarriage, engine, etc ... in a cramped internal layout. The power plant, along with the fuel, took up most of the internal space, and covered about half of the tubular form. The front end was tapered to a sharp point while the cockpit tub was well positioned in the forward part of the design, offering up exceedingly good visibility when in flight or taxiing. The single engine was fed by two small half-circle intakes along the sides of the fuselage, just aft of the cockpit. The intake openings were fixed and not variable and were fitted with cones to regulate the turbojet airflow at high speeds.

Perhaps the most distinct element of the Starfighter’s design lay in the use of its straight, stubby wings that were only 4in at its thickest. Sweepback was only utilized on the leading edges and a slight anhedral was present to help combat “Dutch Roll,” an aerial phenomenon that forces the aircraft to sway or rock from side-to-side. The wings made up a big component of the aircraft’s supersonic capabilities and were found with edges so sharp that they presented dangers to the ground crews servicing the aircraft to the point that special protectors had to be issued to these areas.

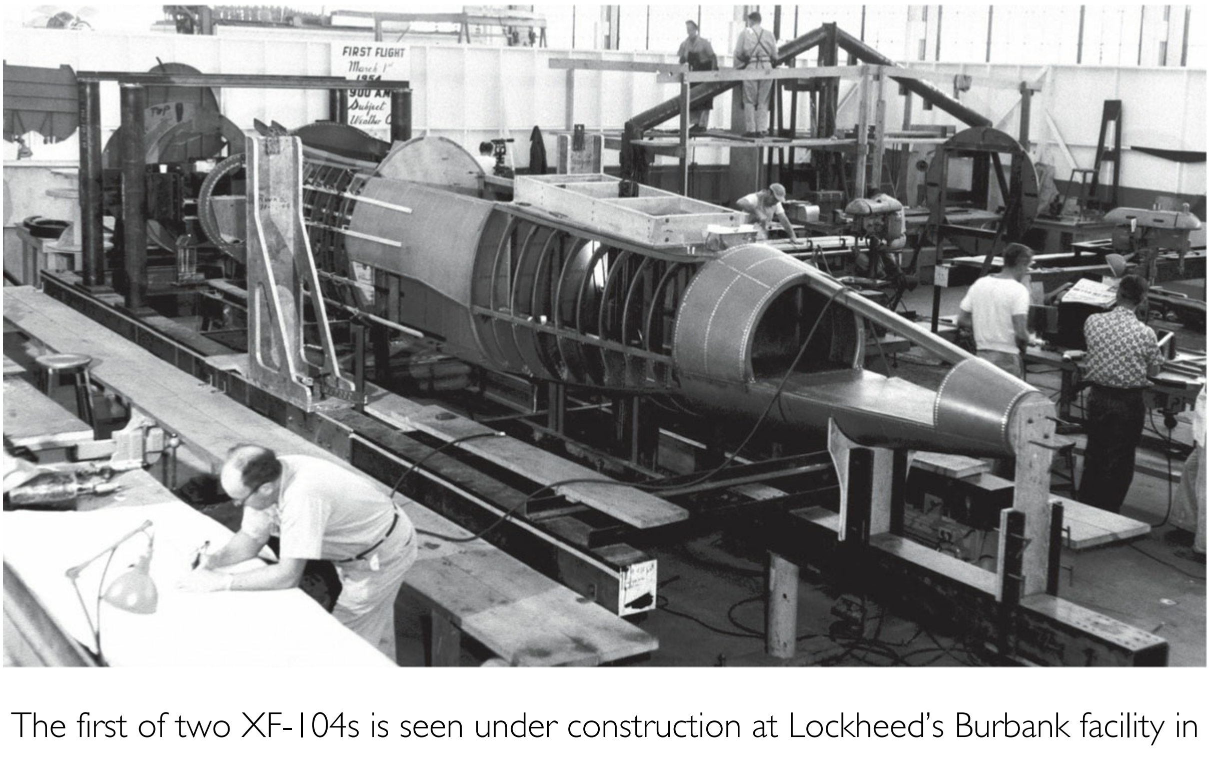
The empennage completed the design and sported its stabilator towards the topmost edge of the vertical fin. The horizontal surfaces were a smidgeon in size smaller than those of the main wings, forcing engineers to add anhedral to the main wings. The top-mounted horizontal surfaces also combated inertia coupling: another dangerous aerial phenomenon consistent with high-speed flight.



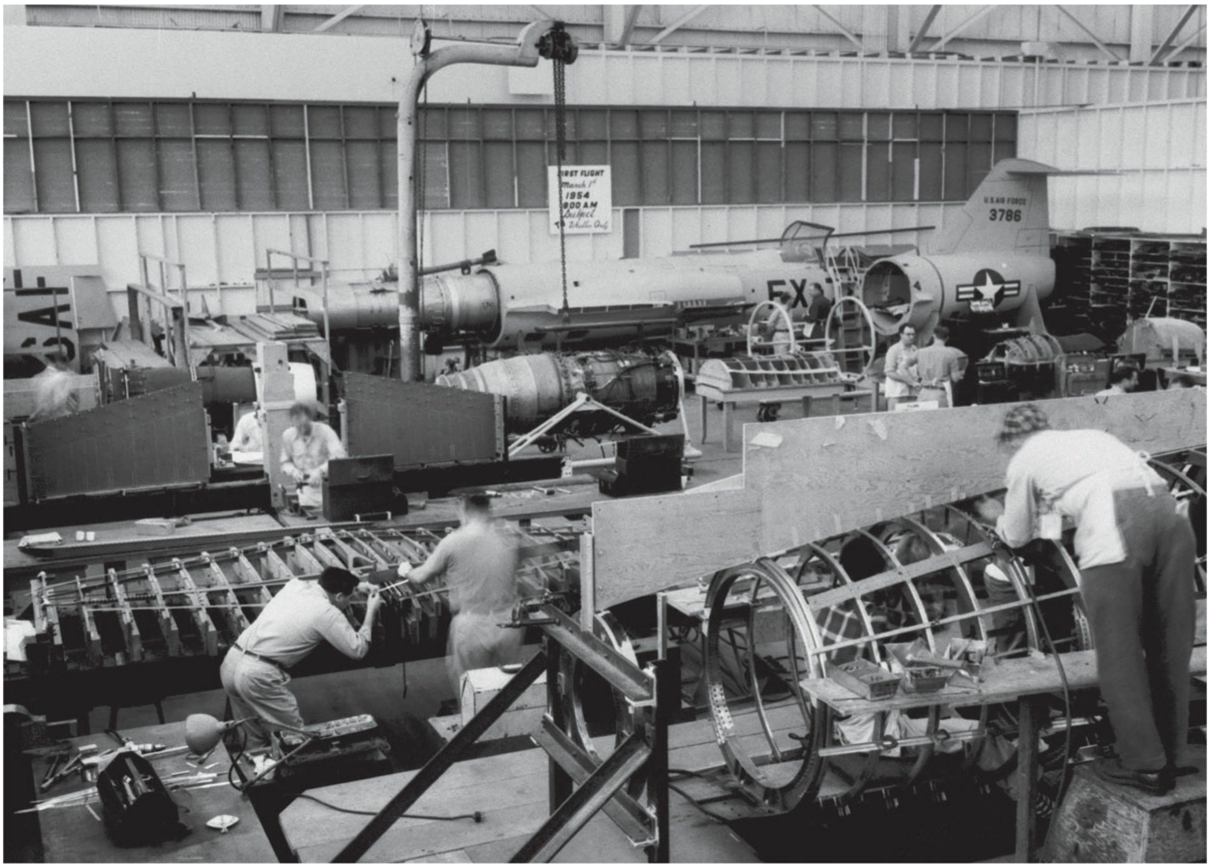
A look-down view of the prototype XF-104 Starfighter. This was before they installed the supersonic inlets as the first flights of the XF-104 were powered by a non-afterburning Buick-built Wright J65-B-3 turbojet, not with the General Electric J79-GE-19. (EAFB/HO)



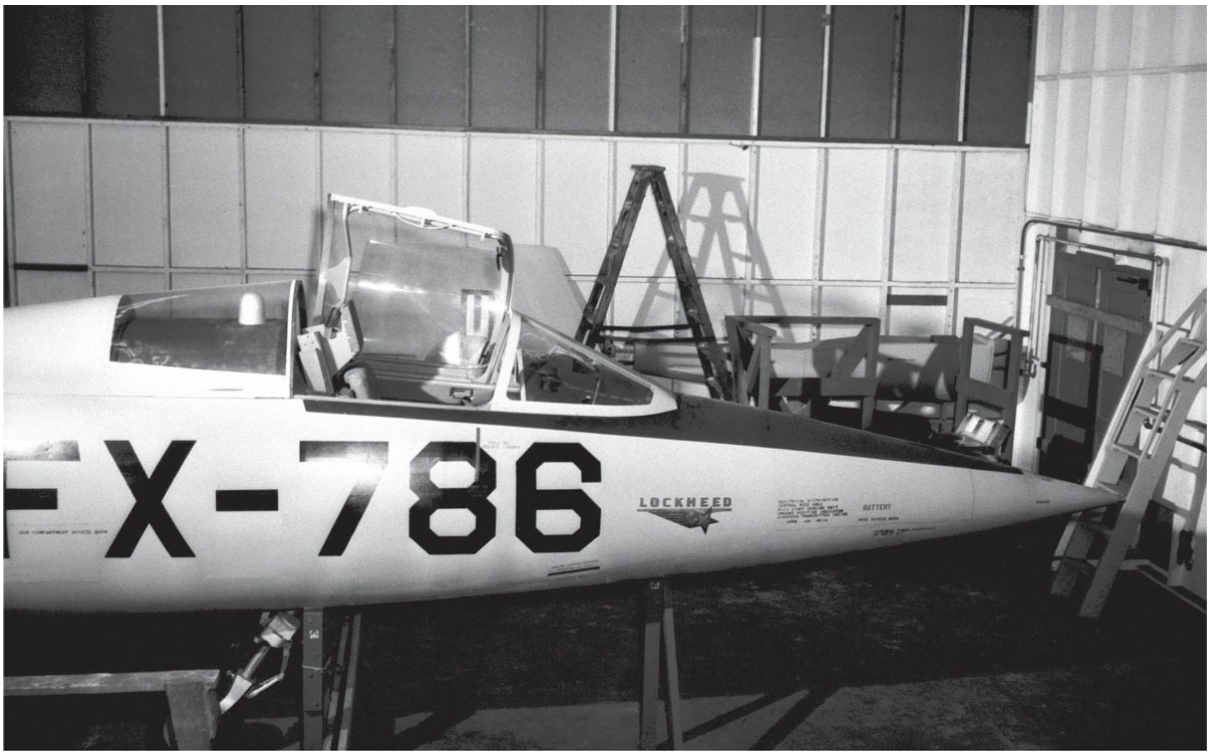
A nose-on view of the XF-104 with its inlets still classified and sheet metaled over for early photo shoots. (EAFB/HO)


FIRST FLIGHT
March 1st
1954
900 AM
Subject
Weather

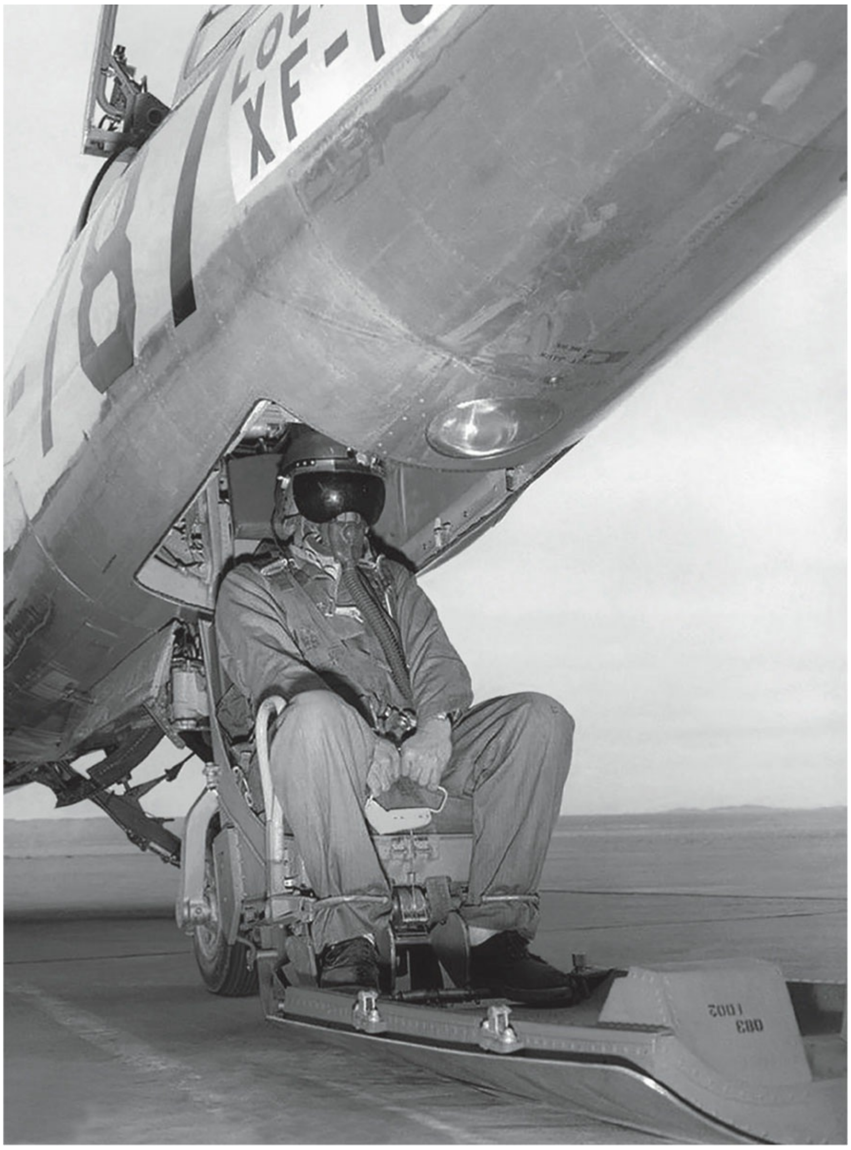
The first of two XF-104s is seen under construction at Lockheed's Burbank facility in the early 1950s. (EAFB/HO)


1954
U.S. AIR FORCE
3786
FX

The buildup of the first two XF-104s with the full-scale mockup in the background. (EAFB/HO)



The finished XF-104 mockup, containing a complete cockpit with ejection seat and, in a weight-saving move, manually retractable nose landing gear. As with the U-2, the F-104 family was designed and built with a side-hinged canopy. (EAFB/HO)


XF-1
787
1002
083

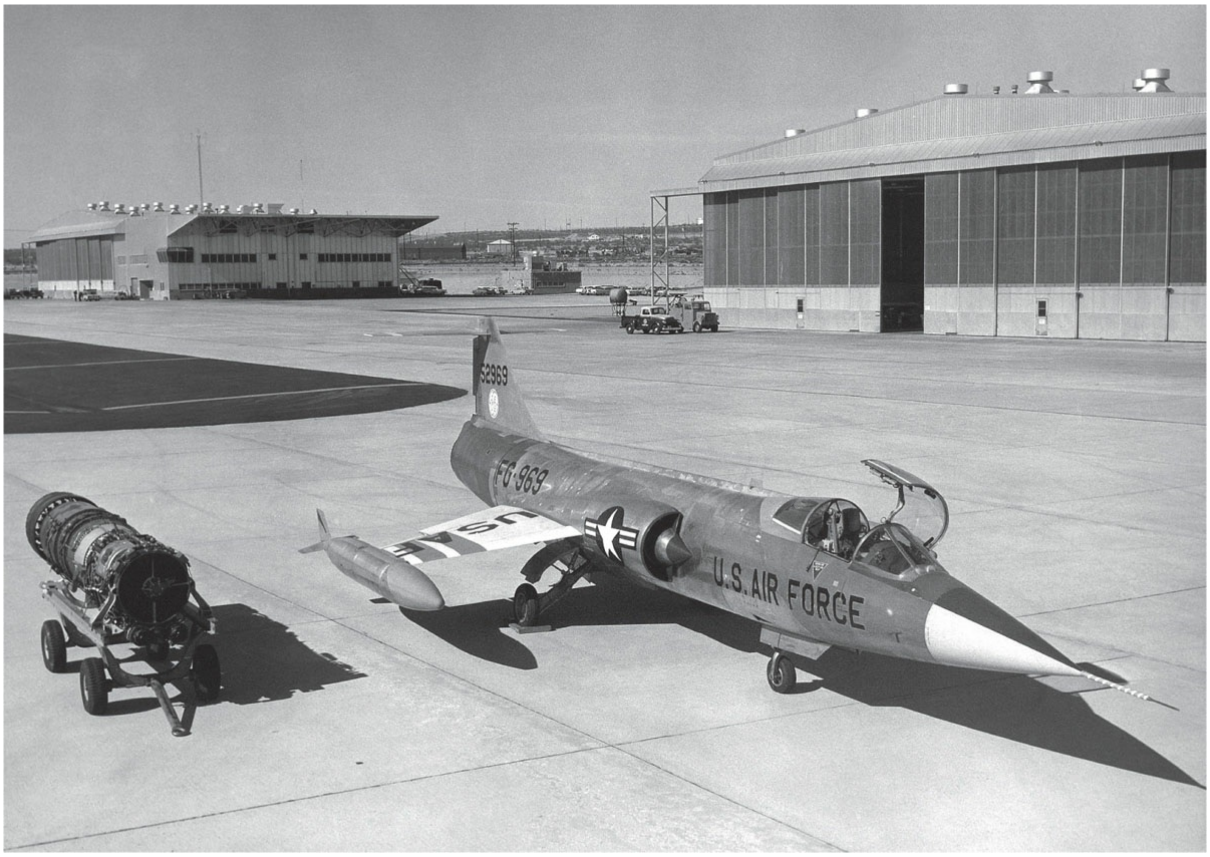
The downward firing of the early XF-104s and early F-104As was an idea that was first considered for the Republic XF-103. It was a short-lived idea. (EAFB/HO)

U.S. AIR FORCE
37787
LOCKHEED
USAF
FG-787
LOCKHEED
XF-104

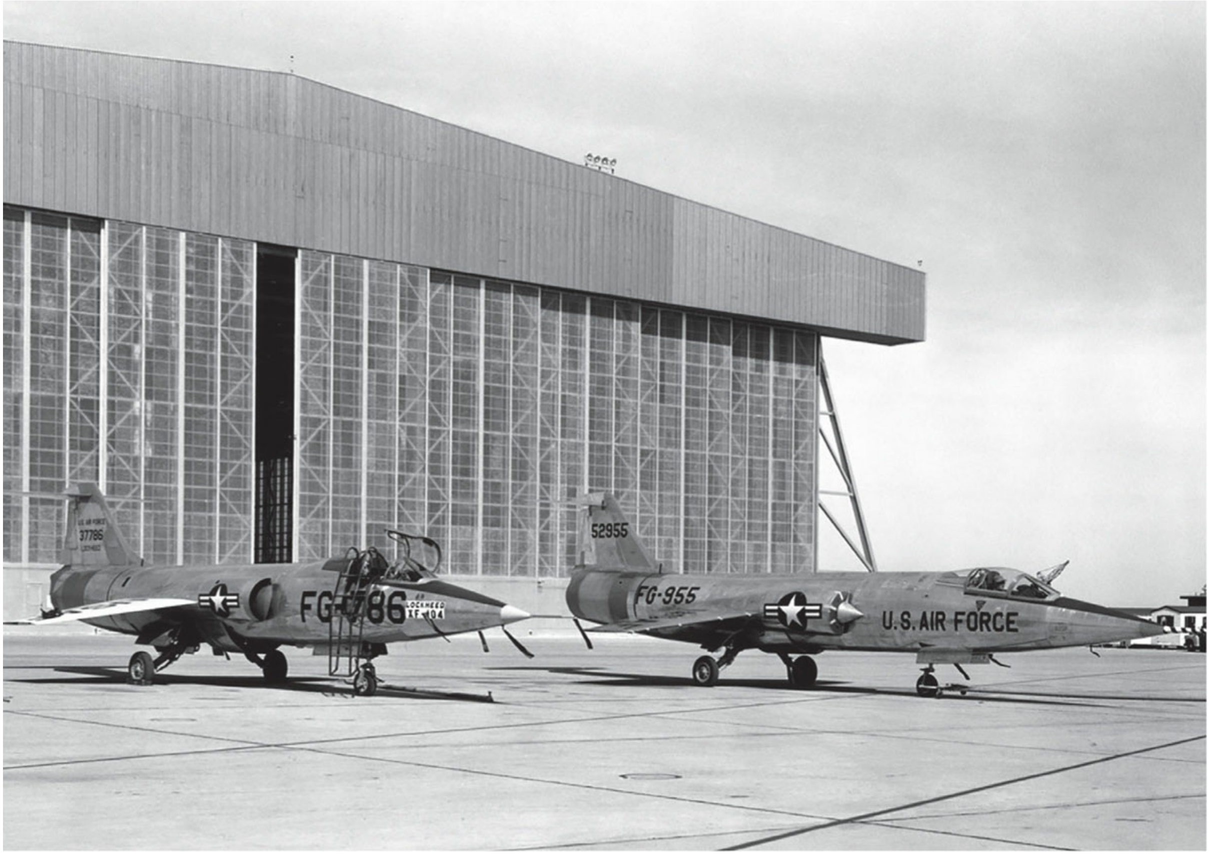
An aerial view of the second XF-104 taken in early 1955 over the San Gabriel Mountains just north of Los Angeles. (Lockheed Martin)

LOCKHEED
FG-78

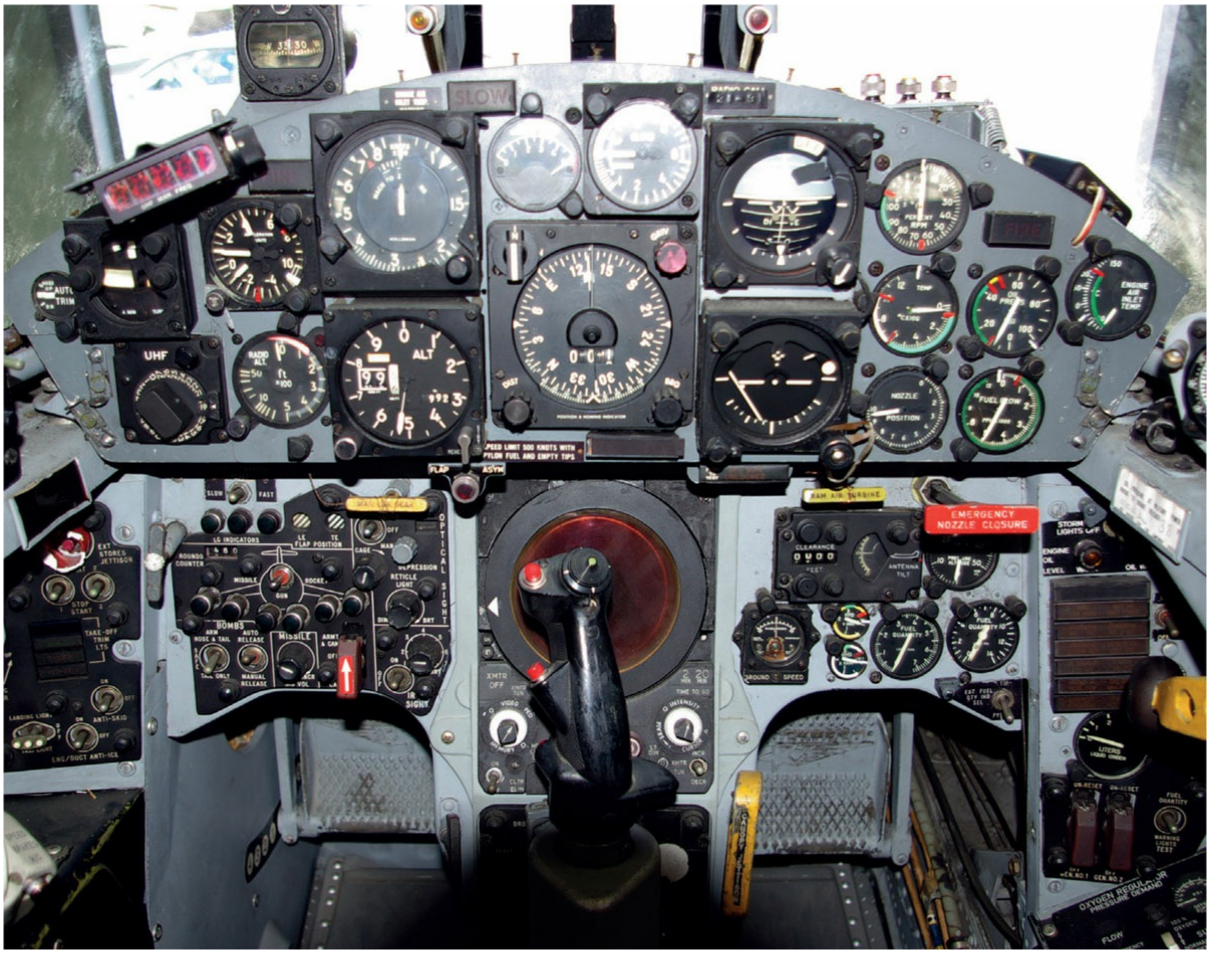
The prototype XF-104s were thrust limited to about Mach 1.75, with the second XF-104 reaching Mach 1.79 on 25 March 1955. (Lockheed Martin)


52969
FG-969
USAF
U.S. AIR FORCE

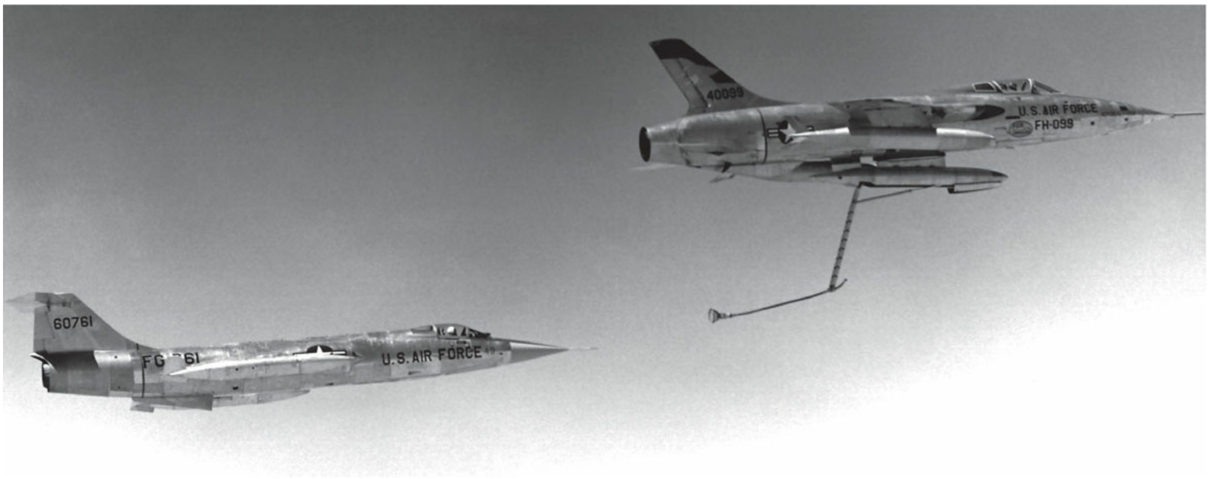
As the F-104 began to mature, the new General Electric J79-GE-13 is displayed next to the beautiful lines of the Lockheed F-104A. (USAF)


LOCKHEED
XF-104
52955
FG-955
U.S. AIR FORCE

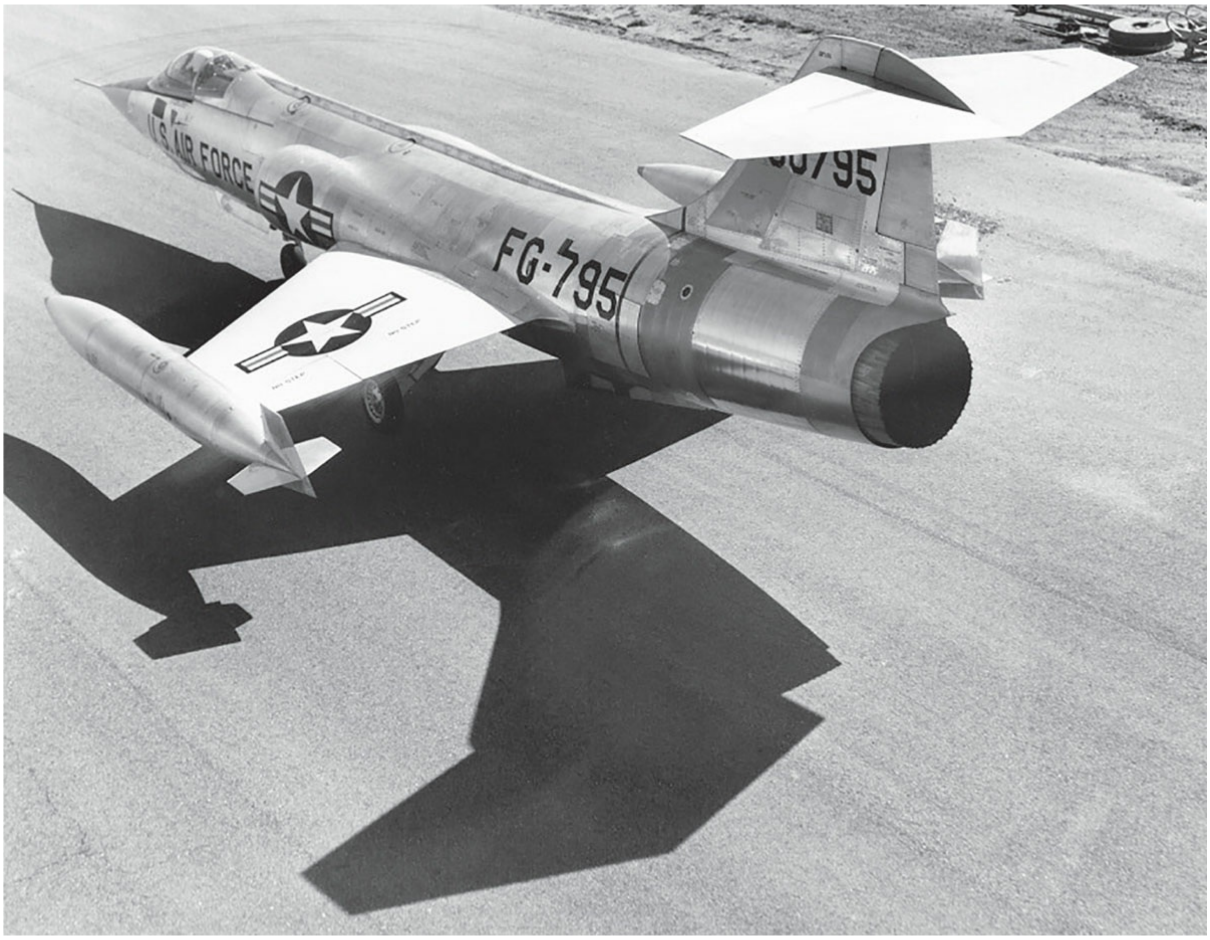
On display in front of one of Edwards' hangars are the first XF-104 prototype and YF-104A 55-2955. Note the increased length of the fuselage and revised air intakes, compared to the XF-104. Also, the XF-104's nose gear retracted backward, while the YF-104A's gear rotated forward. (EAFB/HO)



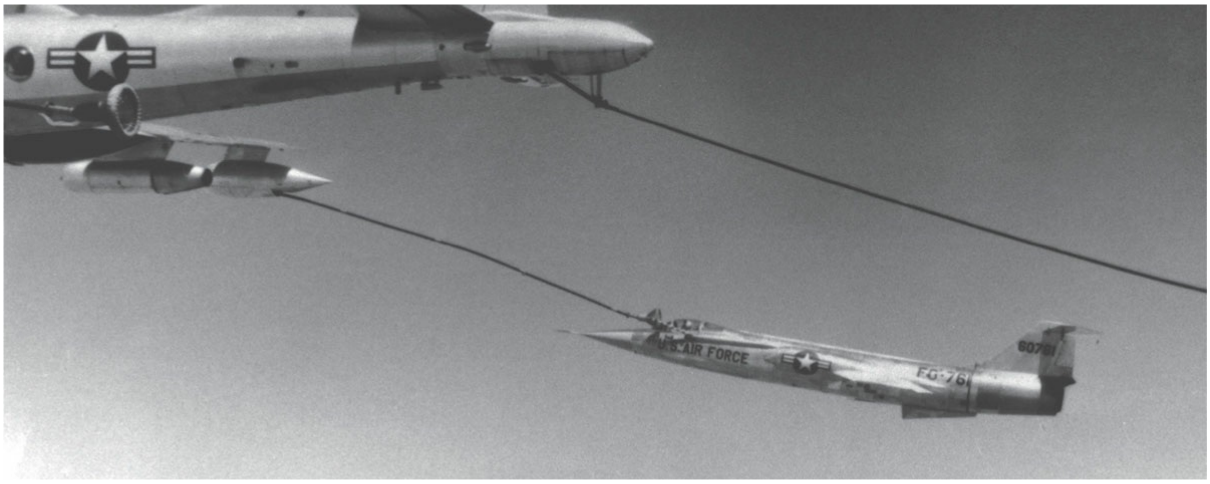
A typical F-104 cockpit instrument panel. (James C. Goodall)


40099
U.S. AIR FORCE
FH-099
60761
FG-761
U.S. AIR FORCE

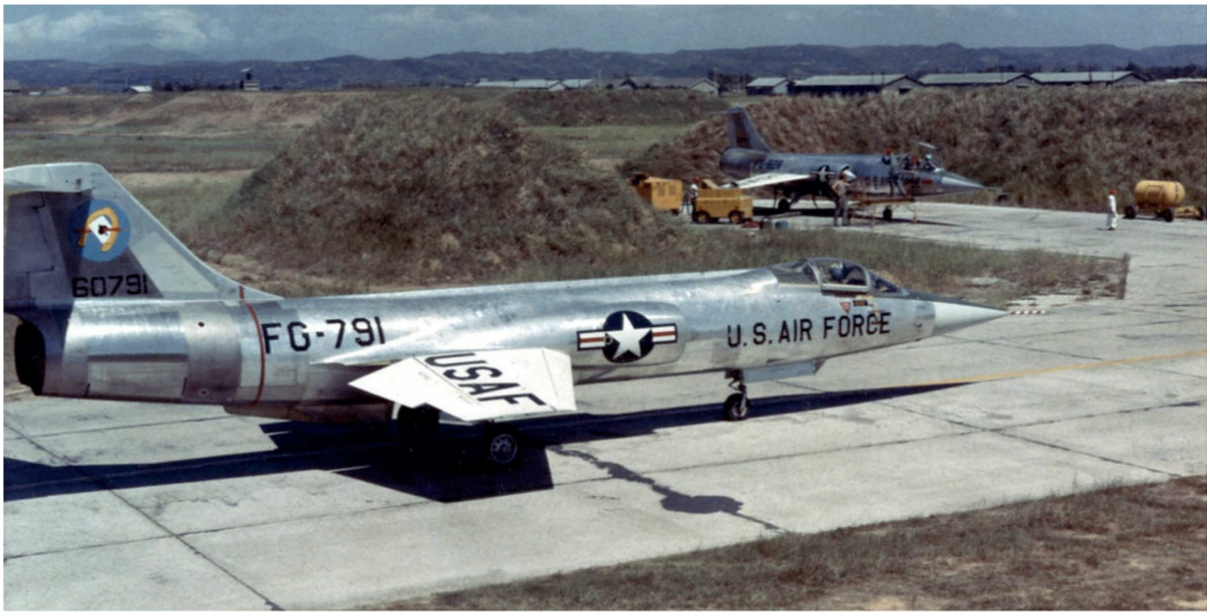
An early model F-104A, 56-761, simulates taking on fuel from the second prototype YF-105A, 54-0099. (Lockheed Martin)


U.S. AIR FORCE
FG-795
60795

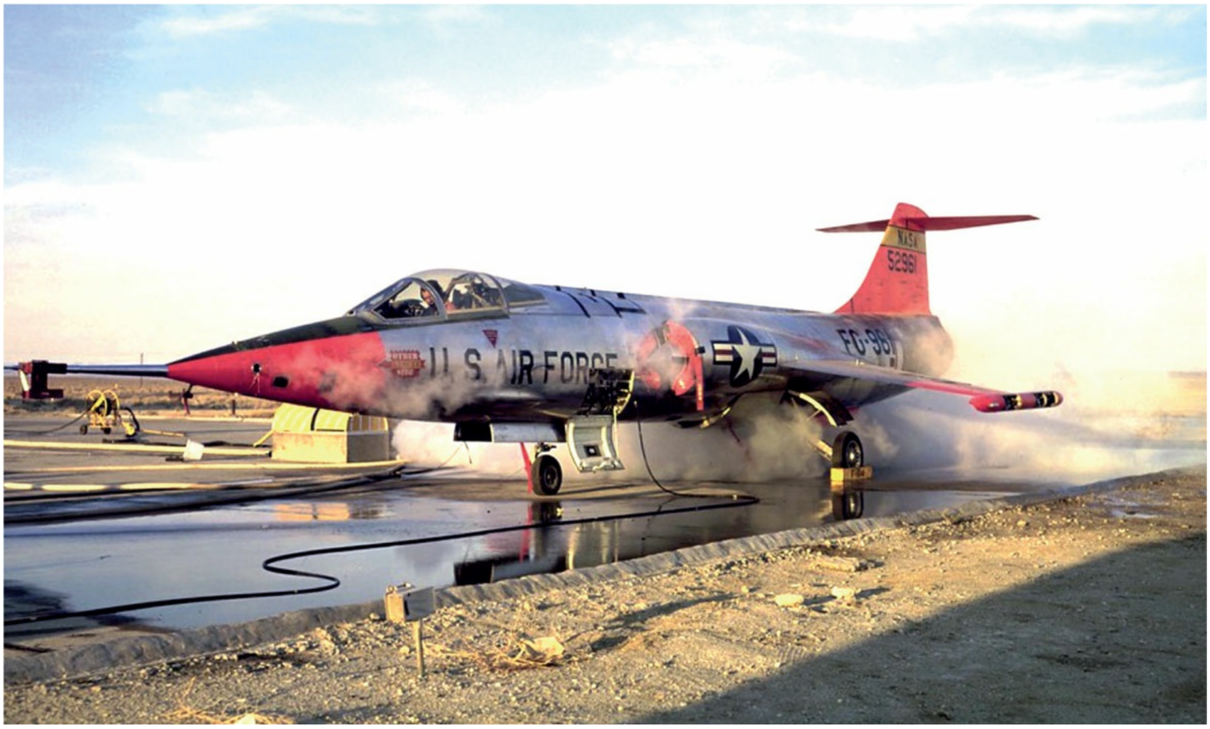
A look-down shot showing off the beautiful lines of Kelly's "missile with a man in it" in 1995. (Author's collection)


U.S. AIR FORCE
FG-761
60761

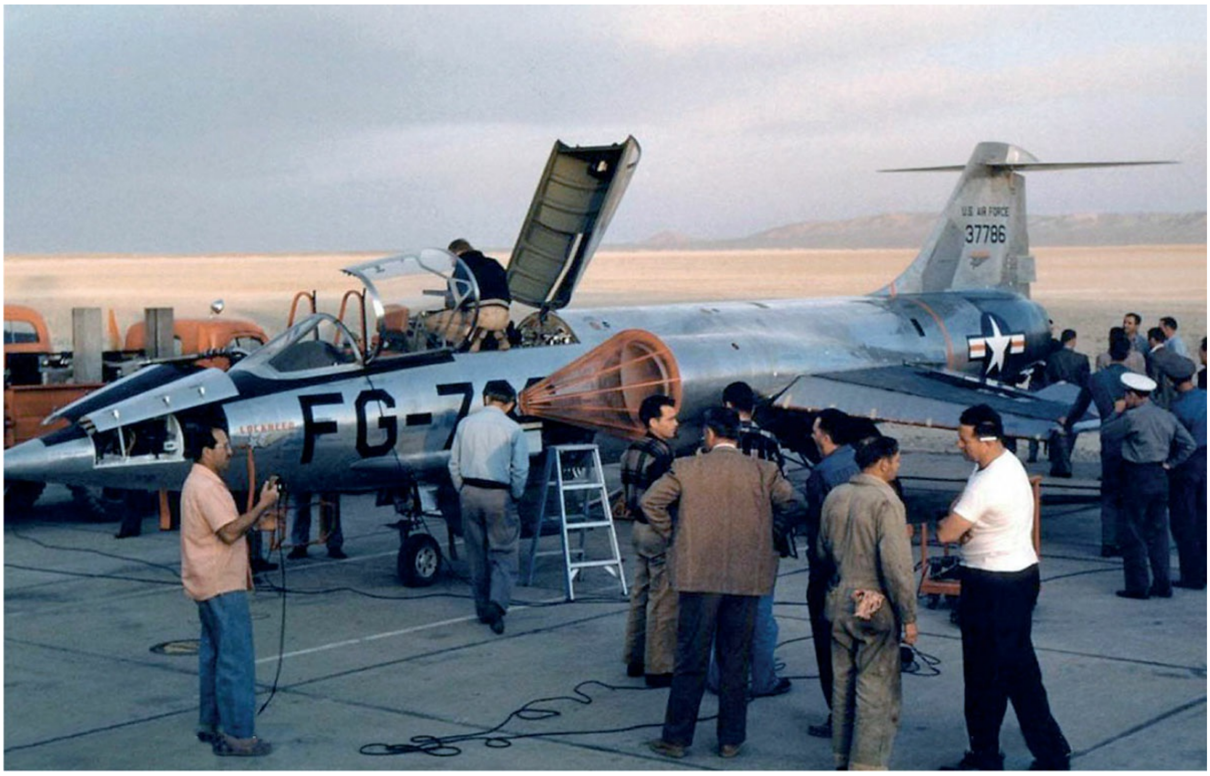
Prior to the simulated in-flight refueling from the YF-104A, the early model F-104A takes on fuel from a Boeing KB-50. (Author's collection)



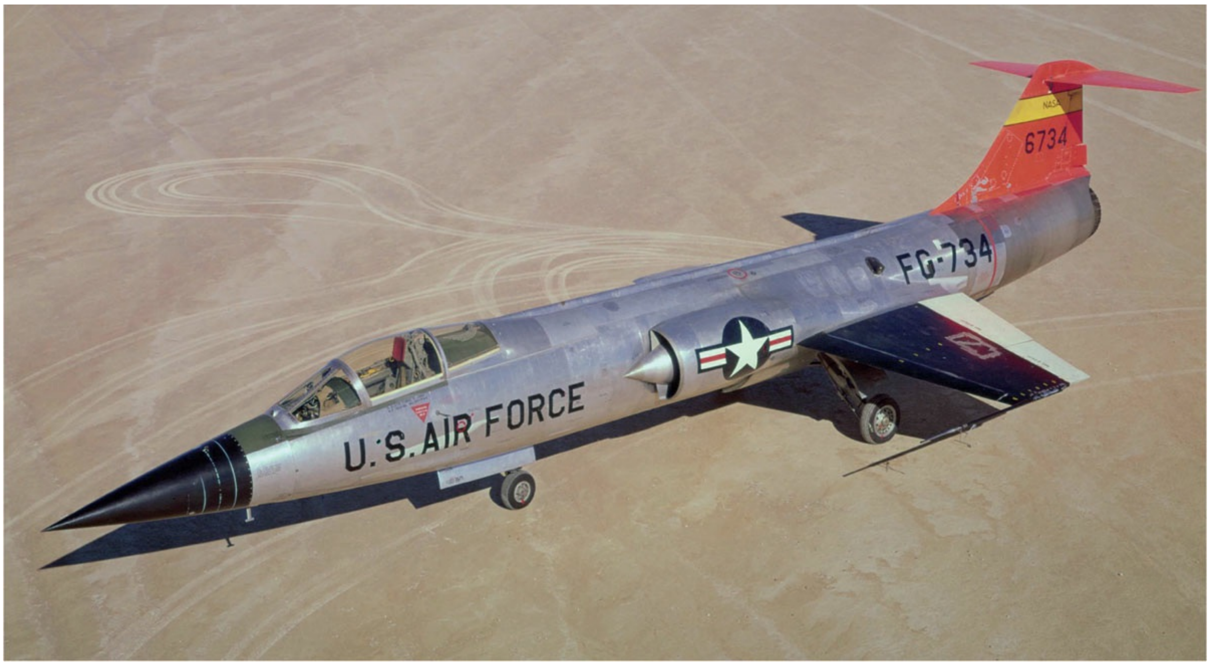
An F-104A assigned to the 83rd Fighter Interceptor Squadron taxis past another F-104A parked in a revetment at the Taiwan Taoyuan AB on 15 September 1958. (Author's collection)



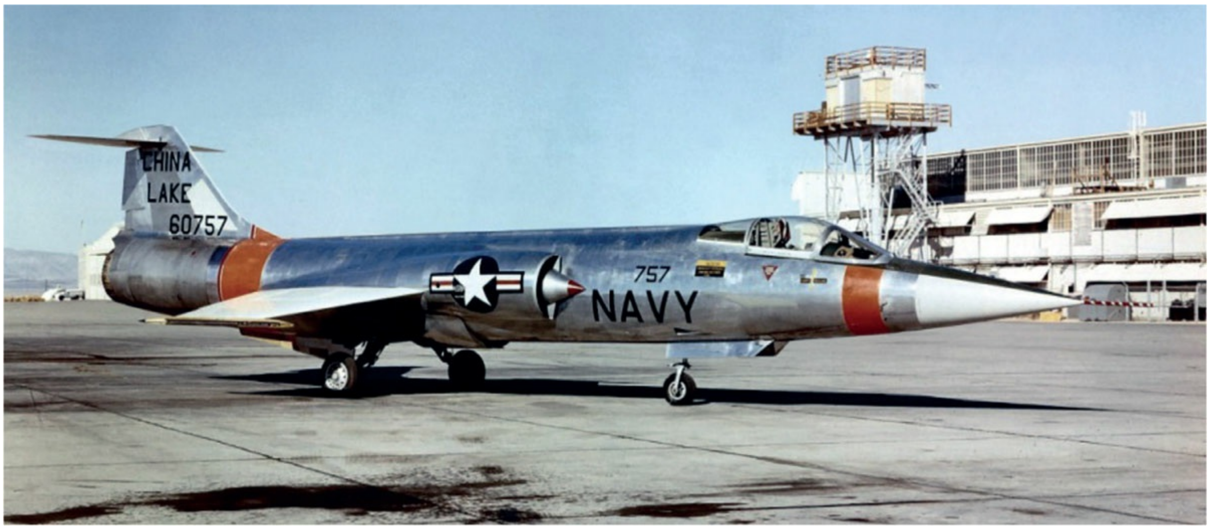
YF-104A 55-2961 was transferred to NASA in 1956 and was modified with the installation of reaction control jets in the nose and the wing tips to control the aircraft in extremely rare atmosphere. After the modification, the designation was changed to JF-104A. In the photo, the JF-104A is seen being loaded with liquid nitrogen, which was used in the nose and wingtip reaction control jets. (NASA)


U.S. AIR FORCE
37786
FG-7
LOCKHEED

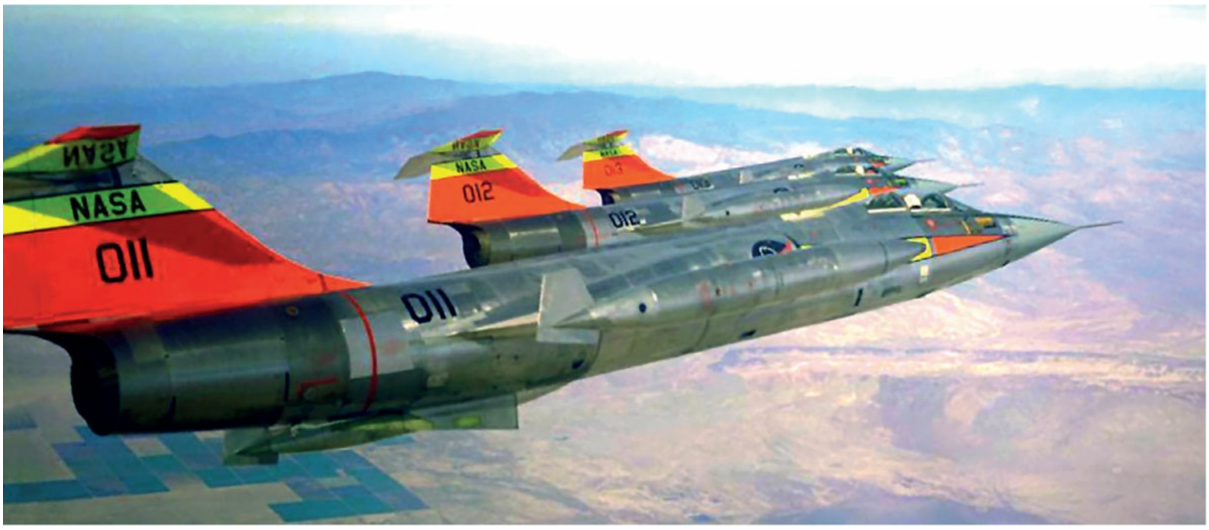
Static ground testing was undertaken at Edwards AFB during late January and early February 1954. (EAFB/HO)


NASA
6734
FG-734
U.S. AIR FORCE

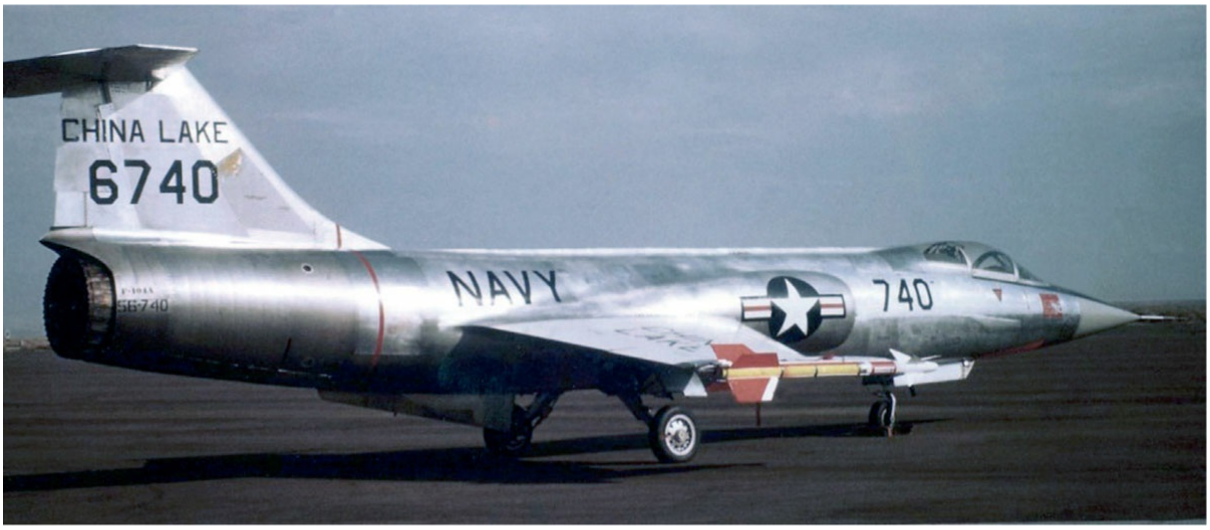
A NASA F-104A, 56-734, photographed on 16 November 1960 on Rogers Dry Lake. (NASA)


CHINA
LAKE
60757
757
NAVY

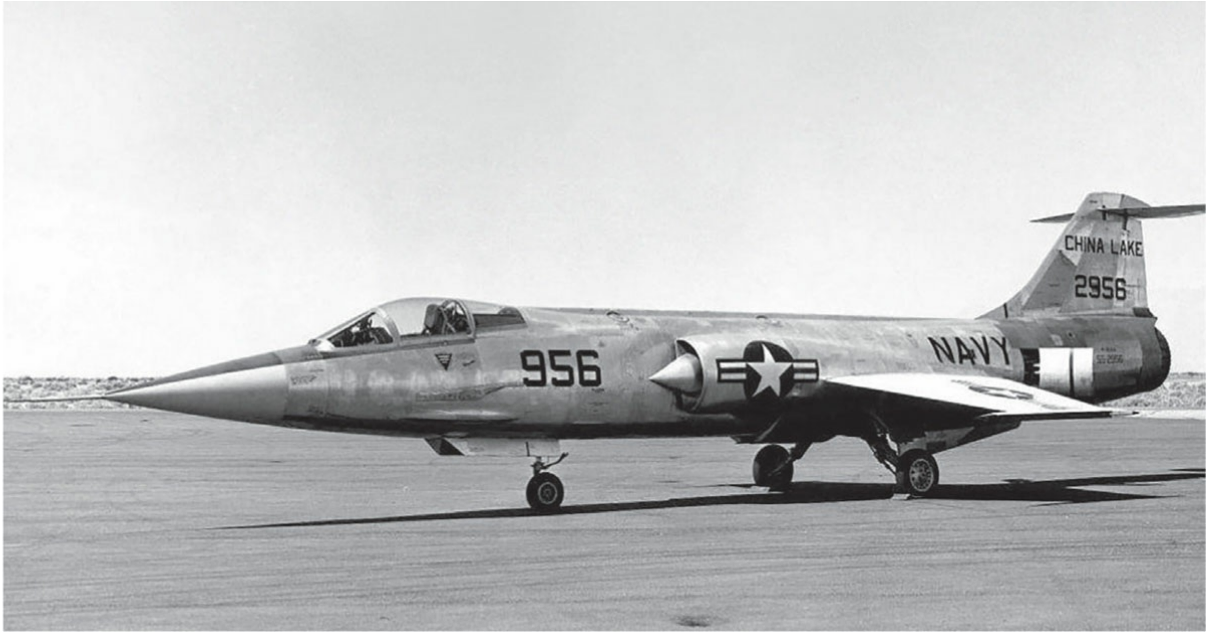
This F-104A, 56-0757, was the third F-104A assigned to the Navy. It was short lived as '757 was lost in an accident on 7 April 1961. (US Navy)


NASA
011
NASA
012
013

In this 24 October 1963 photo, all three NASA F-104Ns are flying in formation. (NASA)


CHINA LAKE
6740
NAVY
740
56-740

This Navy F-104A, 56-0740, carries an AIM-9 Sidewinder. It was configured for test work at China Lake Naval Air Weapons Station (NAWS). (US Navy)


CHINA LAKE
2956
NAVY
956

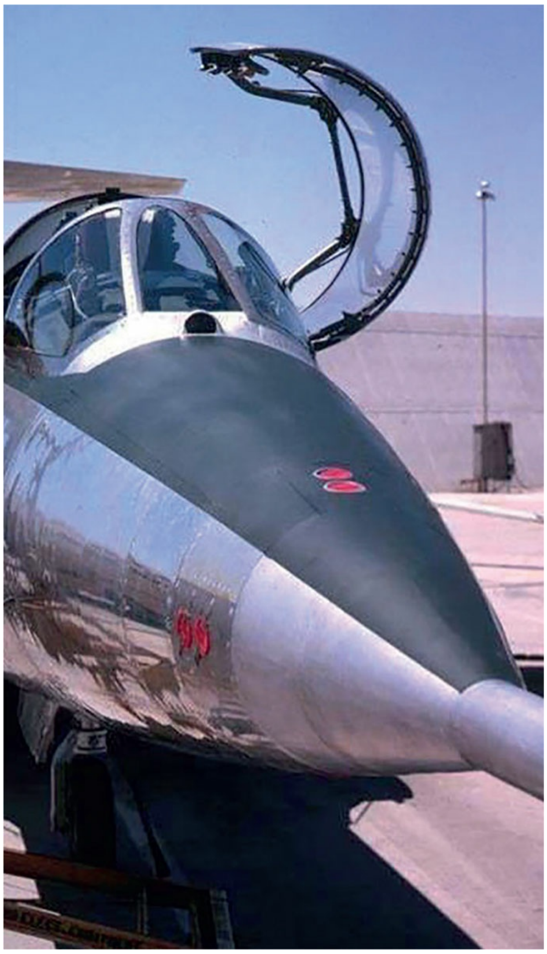
The first of three F-104As assigned to the US Navy for air-to-air weapons testing at high Mach numbers. (US Navy)

0-762
U.S. AIR FORCE
USAF

A three-quarter view of the modified NF-104A shows off its slim design that gave the F-104 the look of a missile. (EAFB/HO)

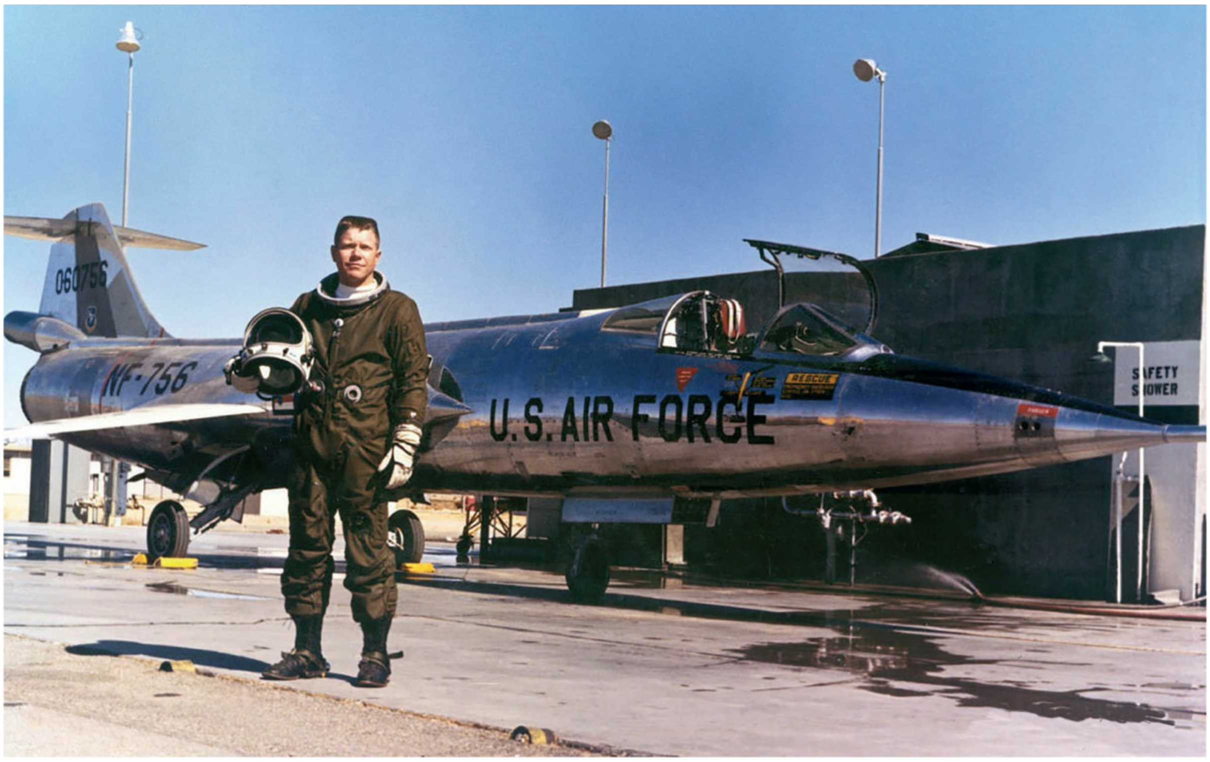
U.S. AIR FORCE
U.S. AIR FORCE

Two of the three modified NF-104As are shown flying in formation over Edwards AFB. (EAFB/HO)

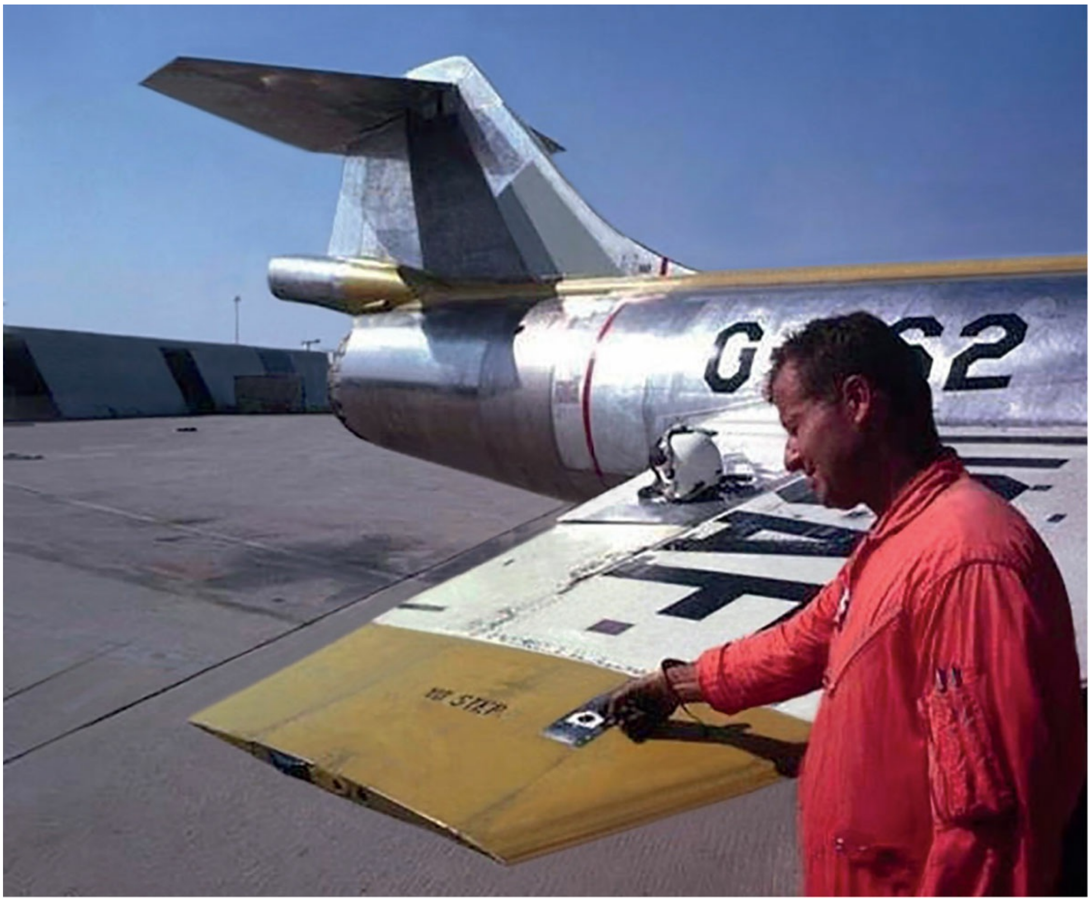


A detailed view of the nose-mounted reaction control jets that allowed the NF-104 to maneuver in very thin air and in zero gravity. (EAFB/HO)

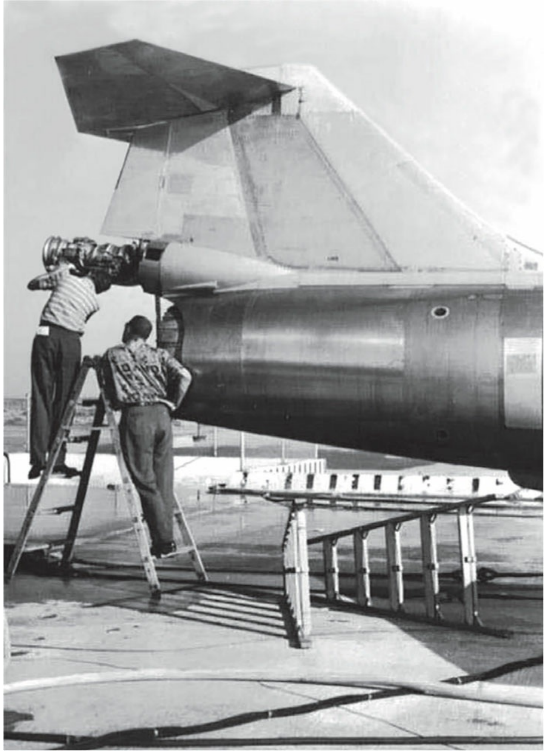
Zoom climbs in the rocket-boosted NF-104A, 56-0756, could top out at 120,000ft in zero gravity for about 80 seconds. (EAFB/HO)


060756
NF-756
U.S. AIR FORCE
RESCUE
SAFETY SHOWER

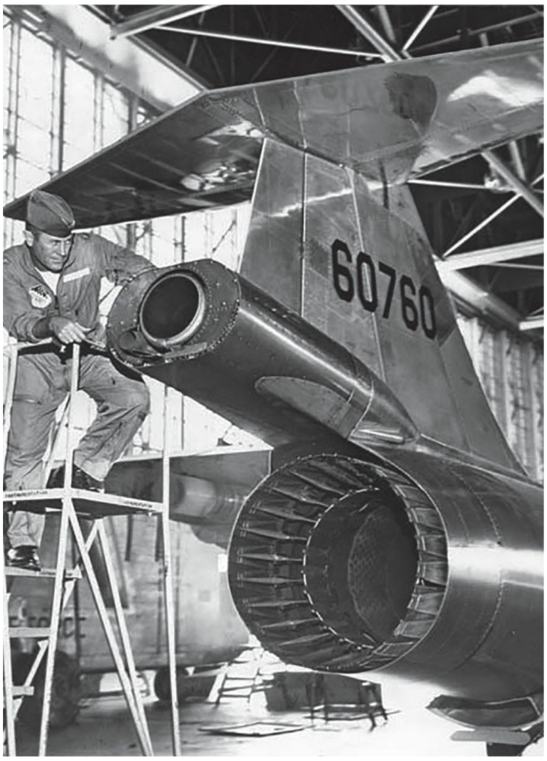
The original of three NF-104As with instructor pilot Dean F. Vikan wearing the high-altitude full-body pressure suit. (EAFB/HO)



The wing span of the NF-104A was increased by the addition of wingtip extensions. This modification was needed to house the Reaction Control System (RCS) roll control thrusters and would also decrease the type's wing loading. (Author's collection)

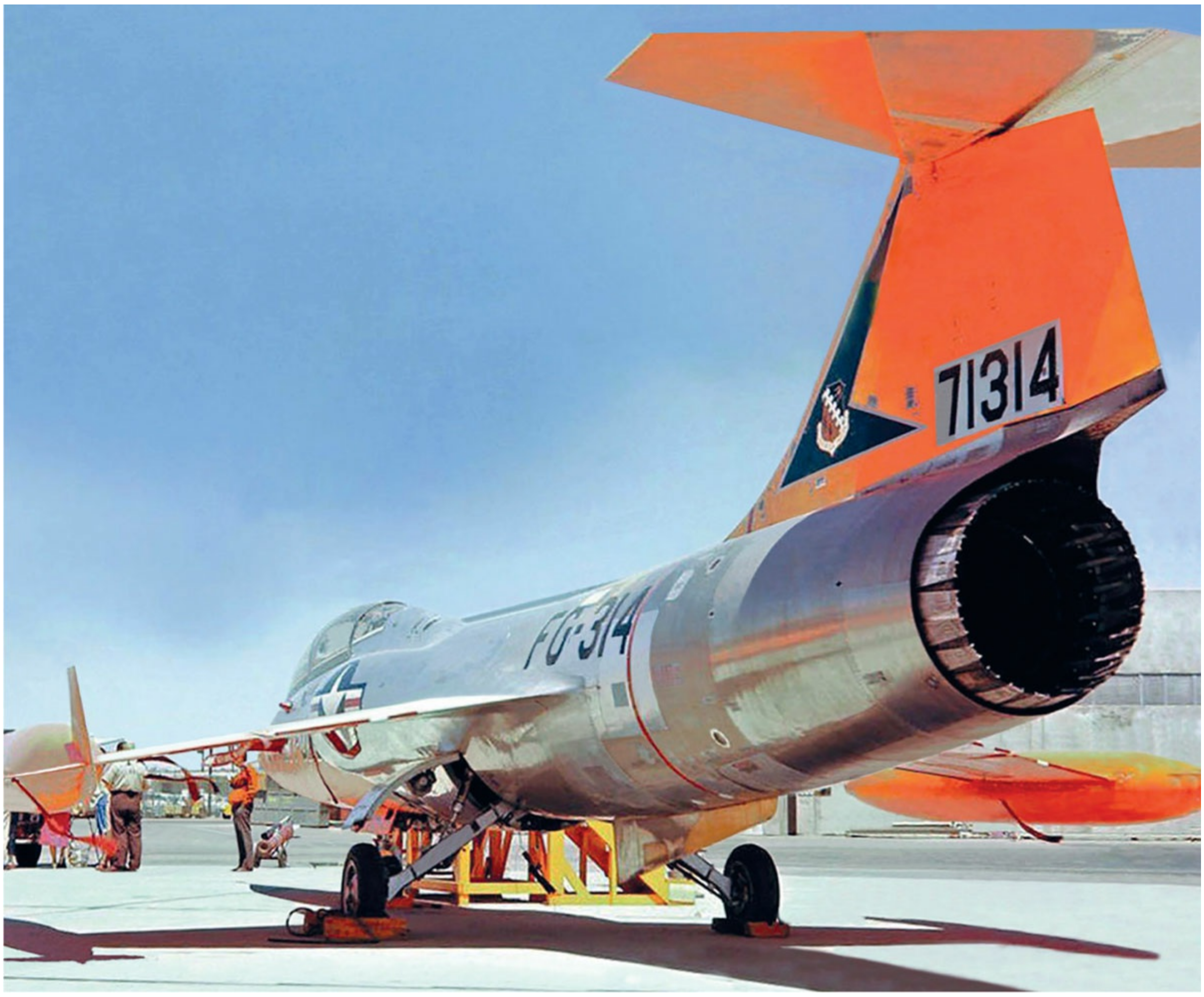


In addition to the standard General Electric J79 jet engine, the Rocketdyne AR2-3 rocket engine was fitted at the base of the vertical fin. (EAFB/HO)

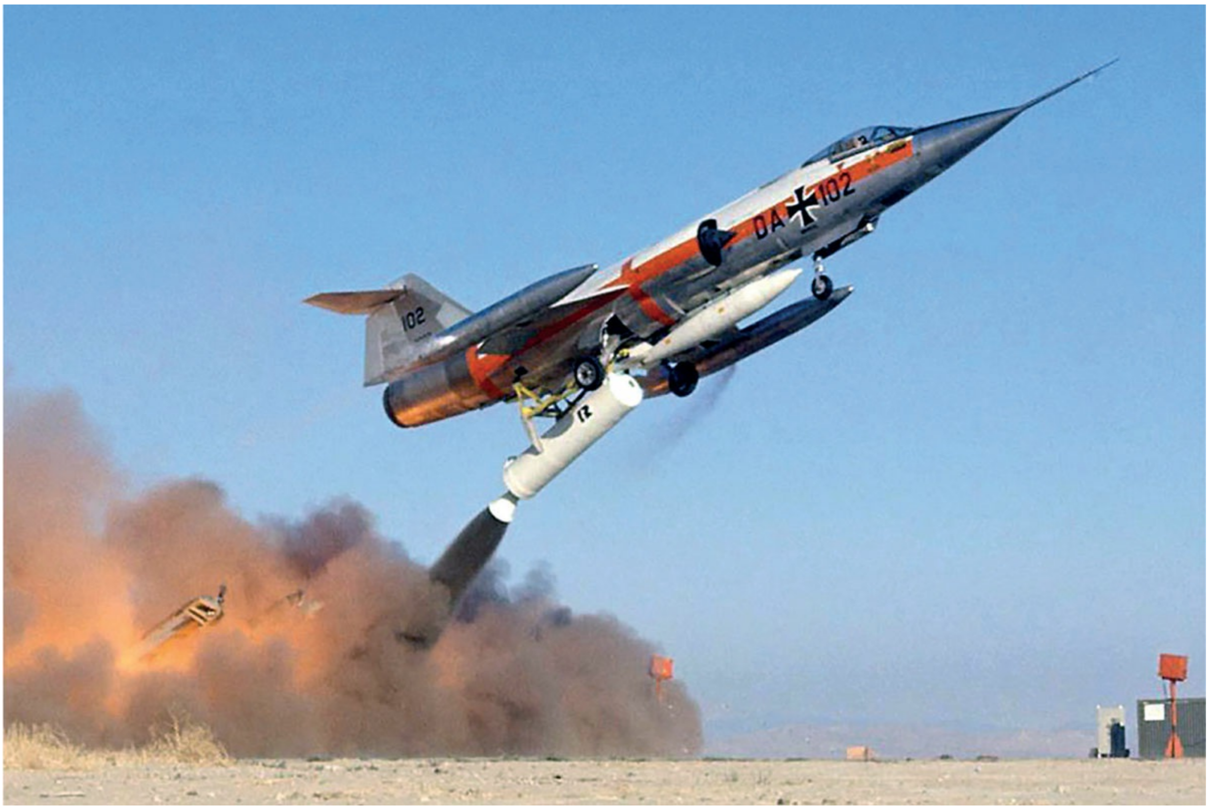


Col Chuck Yeager inspects the business end of the Rocketdyne AR2-3 liquid-fuel rocket engine of this NF-104A. (EAFB/HO)

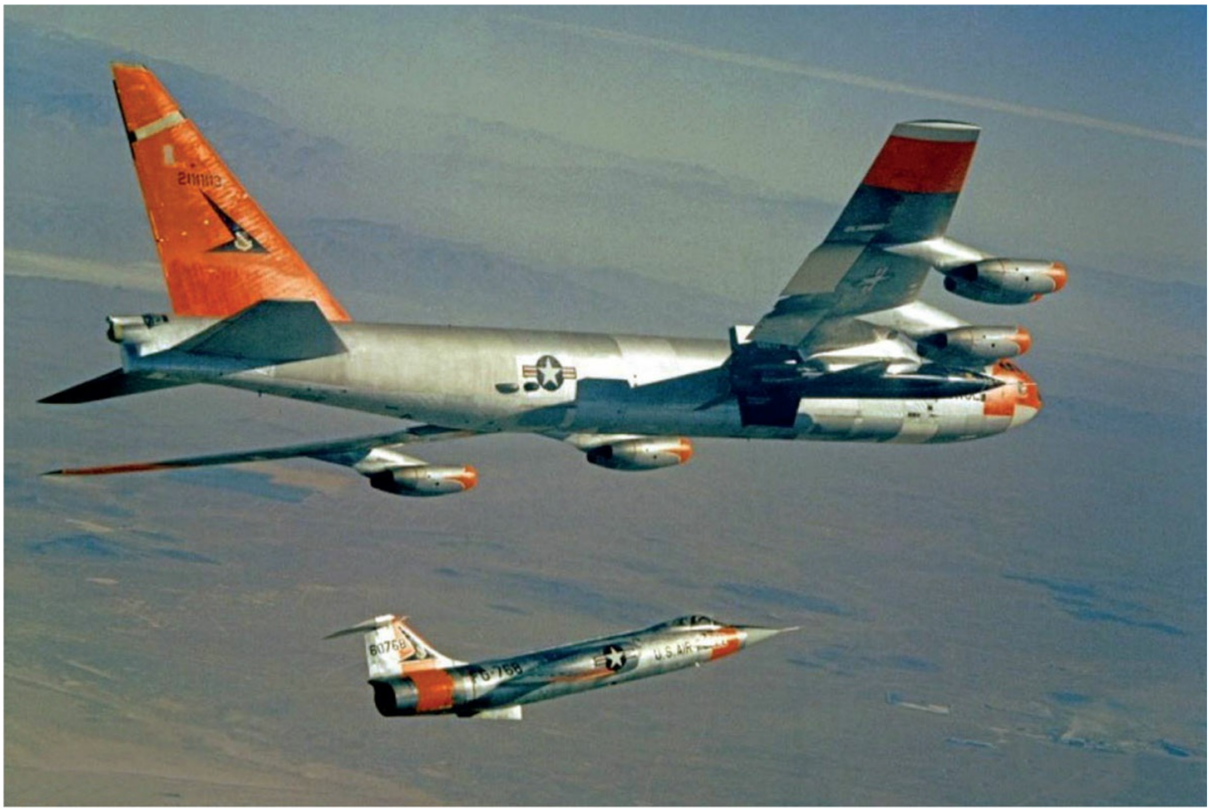
NF-104A 56-0762 was destroyed in the ensuing crash. An investigation later showed that the cause of the crash was a spin that resulted from excessive angle of attack and lack of aircraft response. (EAFB/HO)



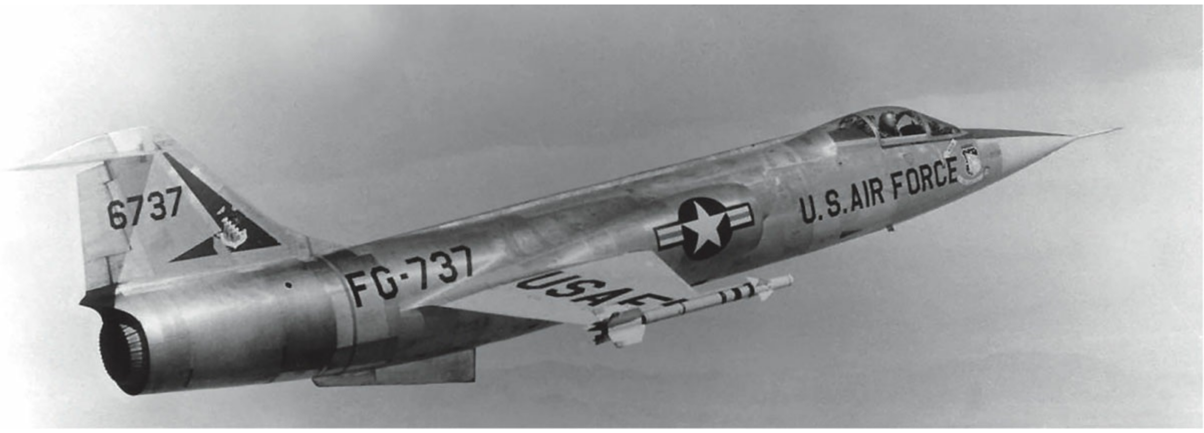
F-104D 57-1314 was assigned to the AFFTC as a chase plane. Its first flight was on 15 October 1958 at Air Force Plant 42 at Palmdale, CA, and it was delivered to the 479th Tactical Fighter Wing on 5 December, 1958. (EAFB/HO)



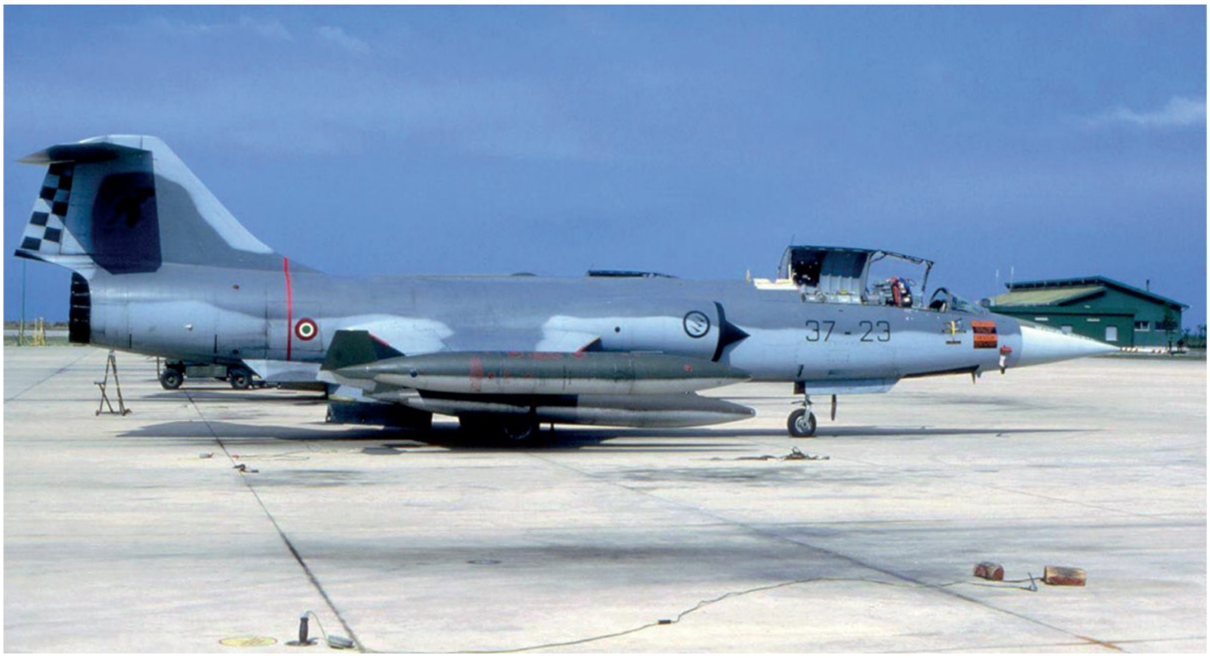
F-104 zero-length launch (ZeLL) test at Edwards AFB in June 1963. West Germany trialled this system to avoid the need for runways – and to avoid being nuked on the ground. (USAF)



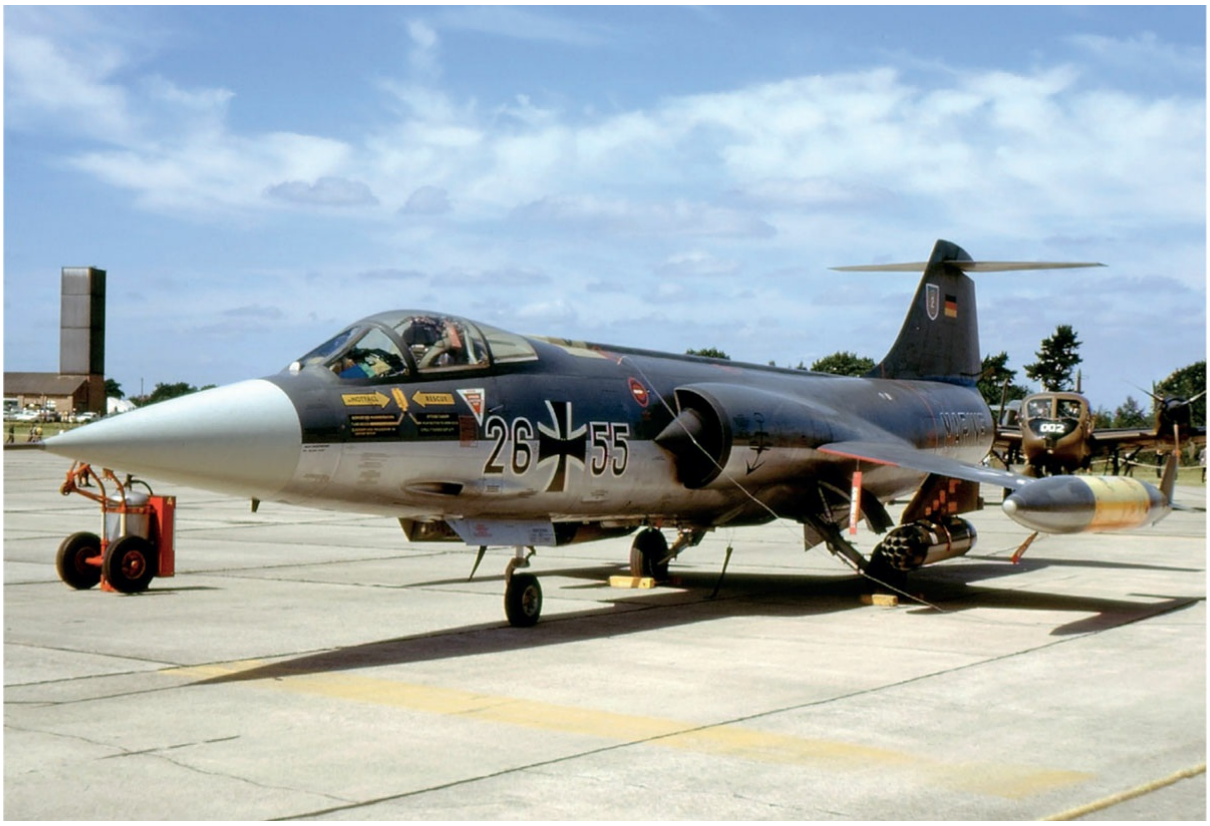
F-104A 56-768, assigned to the AFFTC at Edwards AFB, chasing B-52 "0004" NB-52 Stratofortress with an X-15 under the wing in 1958. (EAFB/HO)



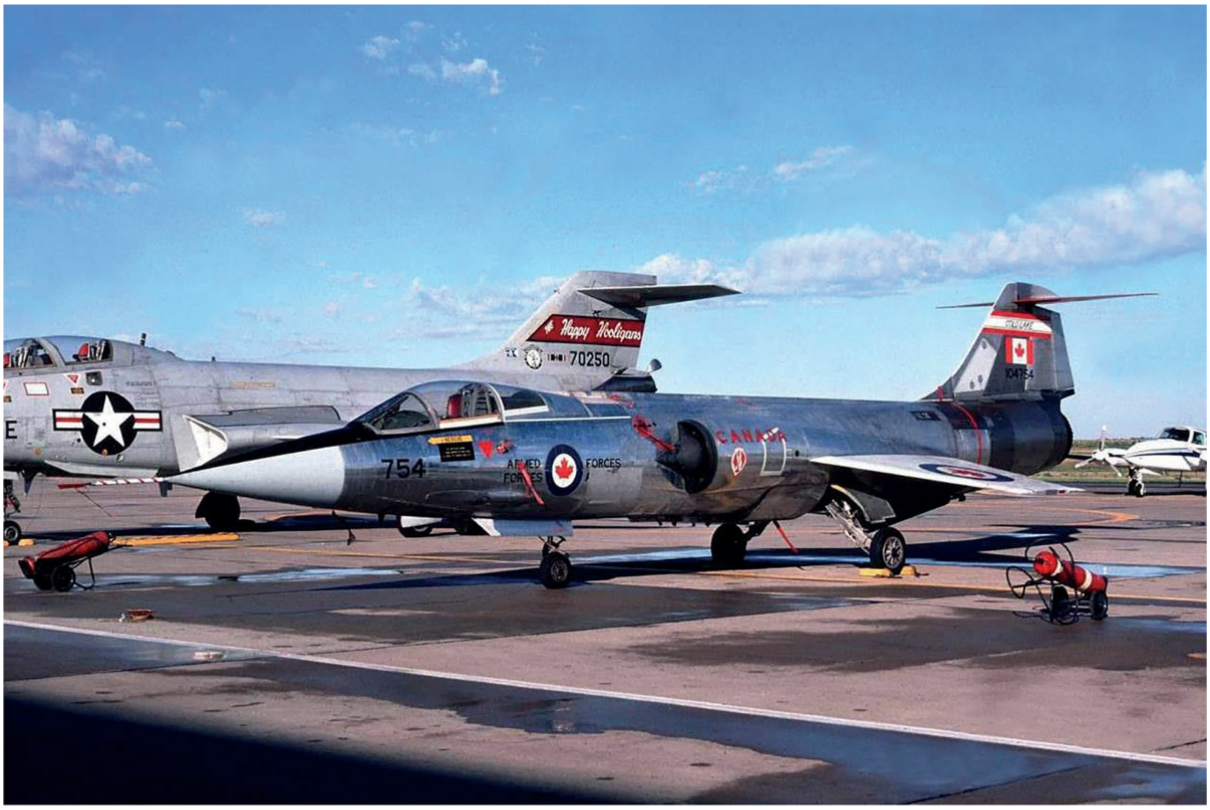
F-104A 56-737 is prepped to launch two AIM-9B Sidewinder infrared-homing air-to-air missiles during weapons testing at Edwards AFB. (EAFB/HO)



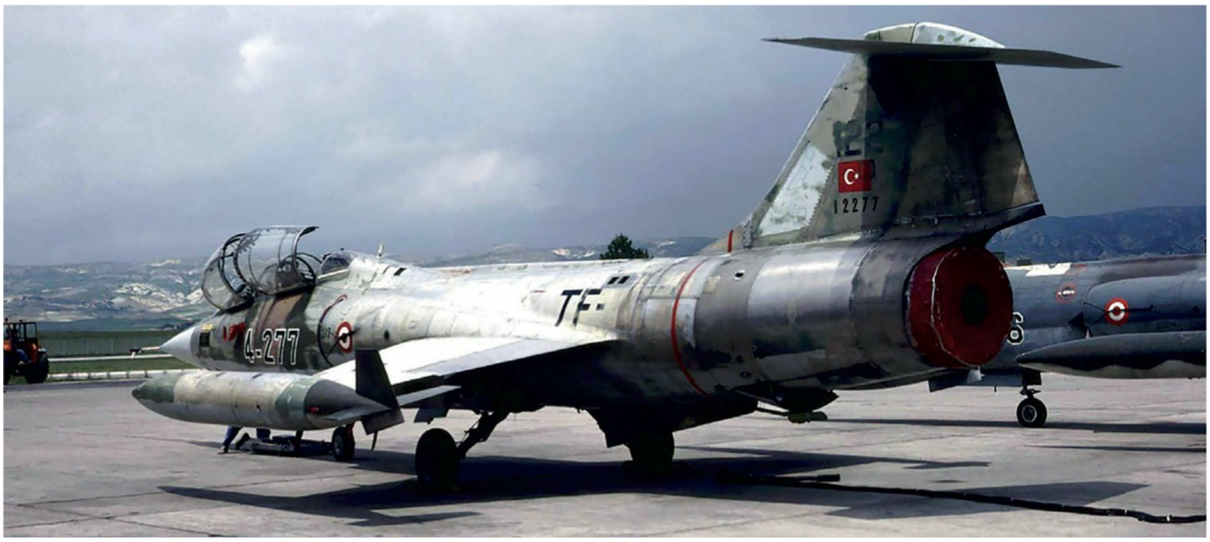
F-104S ASA 37-23 of 18° Group of 37° Wing of the Italian Air Force in a two-tone test camouflage scheme in 1991. (Author's collection)



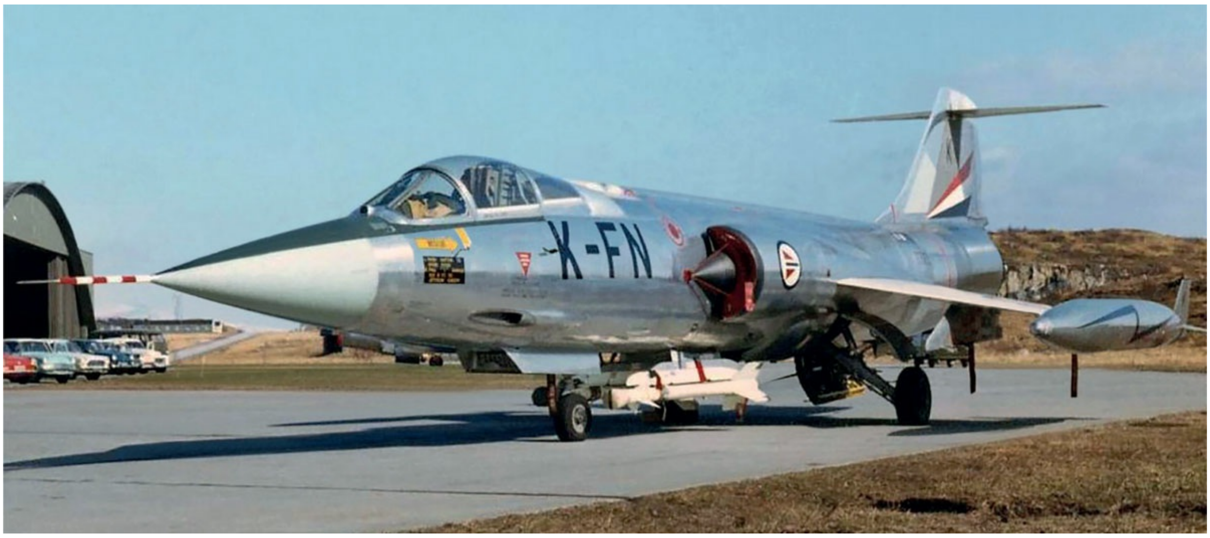
F-104G 26+55 at Utrecht-Soesterberg (UTC/EHSB) in the Netherlands. (Author's collection)



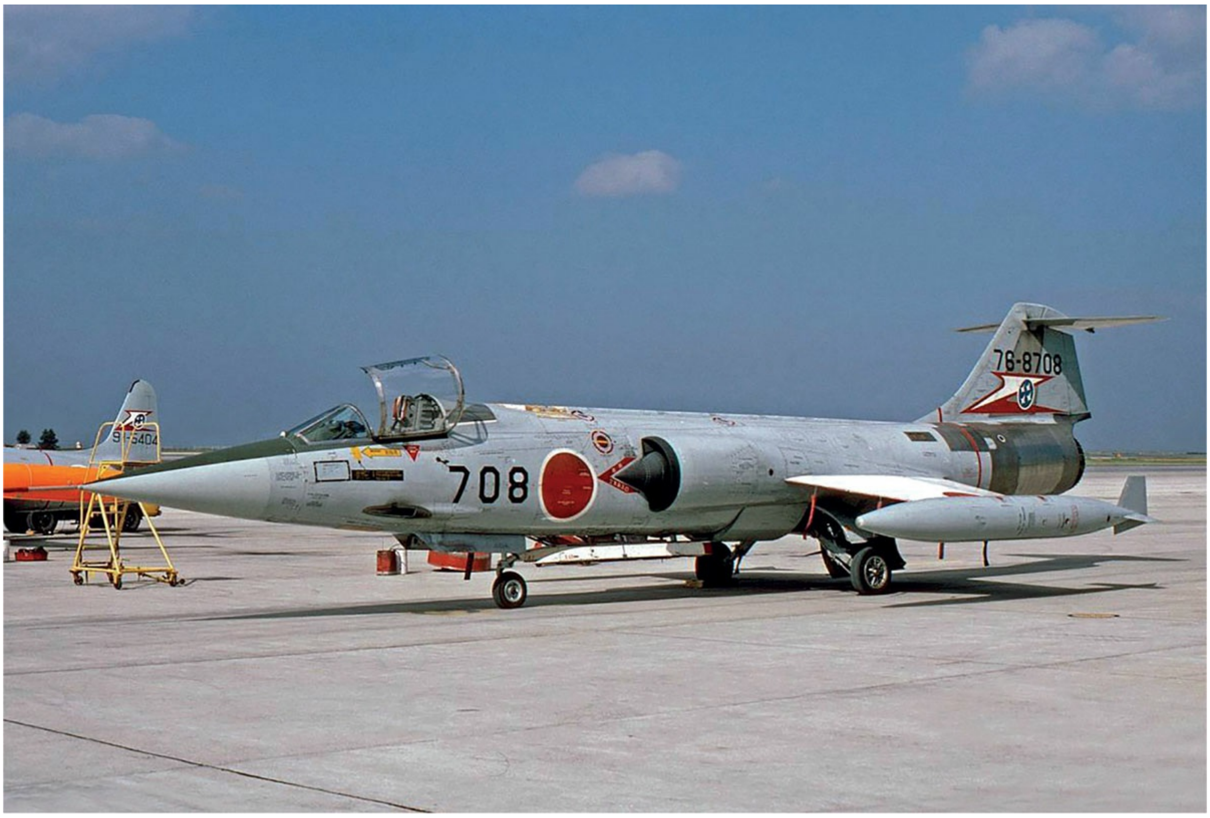
CF-104 “754” of No. 417 Strike/Reconnaissance Operational Training Unit at Cold Lake, Canada. (Author’s collection)



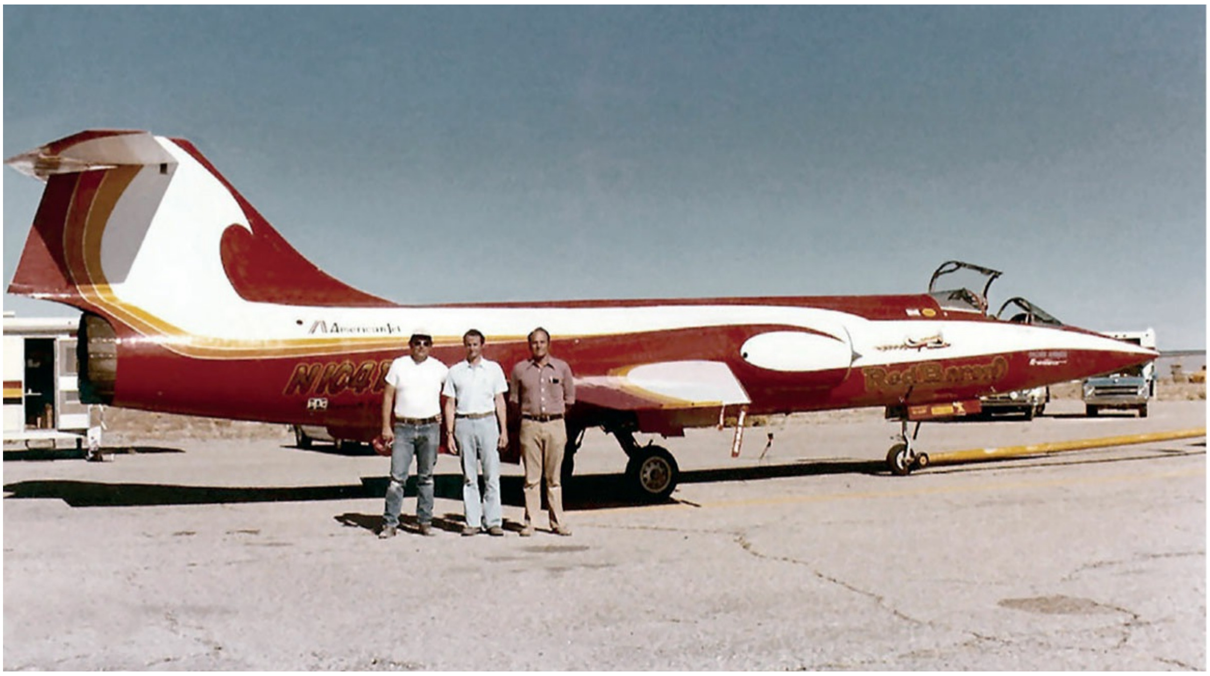
The two-seater TF-104G 62-12299 at Murted, Turkey, in June 1983. (Author’s collection)



F-104G "FN-K," serial number 61-2625, of 331 Squadron Royal Norwegian Air Force from Bodø AB, Norway. (Author's collection)



F-104J "708" (76-8708) of 207 Hikotai, 83 Air Group (wing) at Naha AB, Japan, in 1984. (Author's collection)



With his home-build hybrid F-104 Starfighter powered by a former US Navy Phantom J79 engine, Darryl Greenamyer managed to reach an official world absolute low-altitude speed record of 988.26mph at Mud Lake near Tonopah, NV. (Author's collection)

U-2A-G DRAGON LADY

1955

PROGRAM: U-2A/G

Program: U-2A/G

Name: Dragon Lady

Mission: Strategic reconnaissance

Length: 49ft (14.94m)

Wing Span: 80ft (24.38m)

Height: 15ft 2in (4.63m)

Max T.O. Weight: 24,150lb (10,954kg)

First Flight: 1 August 1955

Last Flight: 17 April 1989

Crew: 1; 2 in the U-2CT trainer

Number Built: 48

Power Plant: 1 x Pratt & Whitney J57-P-37A; U-2C: 1 x Pratt & Whitney J75-P-13 turbojet

Design Speed: Mach 0.71 (518mph; 833.6km/h)

Service Ceiling: 70,000ft (21,336m)

Combat Radius: 2,880 miles (2,503nm; 4,634.9km)

Weapons Load: 3,000lb (1,350kg) of cameras and sensors

On 1 May 1954, despite the breezy spring weather, leaders across Washington DC's intelligence community found themselves breaking out in a cold, panicked sweat. Over the skies of Red Square in Moscow, the Soviet Union had just introduced its newest bomber, the Myasishchev M-4, ominously nicknamed "Hammer" during a Russian May Day celebration.

Coming on the heels of the Soviet Union's successful detonation of a hydrogen bomb the previous summer, the unveiling fueled a growing fear that Russia had not only eclipsed the West in terms of both nuclear weapons and bomber production, but was gearing up for a potential attack on the United States as well.

The United States had been allied with the Soviet Union during World War II, only to see it transform into its fiercest Cold War enemy. Penetrating the Iron Curtain had proven far more challenging than US intelligence agencies had anticipated. The vast size of the Soviet Union made it difficult to survey. And when surveillance aircraft were sent to the edges of Russian airspace, Soviet forces often shot them down. President Dwight Eisenhower needed a new set of eyes in the sky. He would get them through the Lockheed U-2 high-altitude reconnaissance aircraft.

The initial designs for what would become the U-2 were created by Kelly Johnson in 1953. Working under the cloak of secrecy in the famed Skunk Works division, Johnson envisioned a light high-altitude reconnaissance aircraft capable of flying above the reach of Soviet antiaircraft fire.

The U-2 borrowed its sleek looks from the profile of a traditional sailplane. Its long, tapered wing allowed it to fly missions covering a range of 3,000 miles and carry up to 700lb of the latest photo reconnaissance equipment to a staggering and unprecedented altitude of 70,000ft.

Unfortunately, by the time Johnson could provide a full proposal to US officials in the summer of 1954, President Eisenhower and CIA Director Allen Dulles had already signed off on two competing designs for a high-altitude reconnaissance aircraft.

Johnson was undeterred. He knew he had the better plane. So, he offered up a deal that no general could refuse. Not only would he assume complete responsibility for any maintenance and service, an entirely new concept in aviation, but he would also have a U-2 in the air in just eight months.

Incredibly, Johnson almost met his own impossible deadline, delivering the first U-2 for a test flight on 1 August 1955, nine months after signing the contract.

President Eisenhower now had his secret weapon, and he was determined to use it to prevent the Cold War from turning red hot.

On 4 July 1956, Hervey Stockman flew a U-2 from Wiesbaden, West Germany, deep into the heart of the Soviet Union, capturing detailed photos of airfields, factories and shipyards previously unattainable by other aircraft.

The plane was tracked by Soviet radar, but Stockman's U-2 flew beyond the reach of Soviet interceptors and antiaircraft fire, returning home with history-altering intelligence. U-2 flights revealed that the Soviets were more concerned with building tractors than tanks.

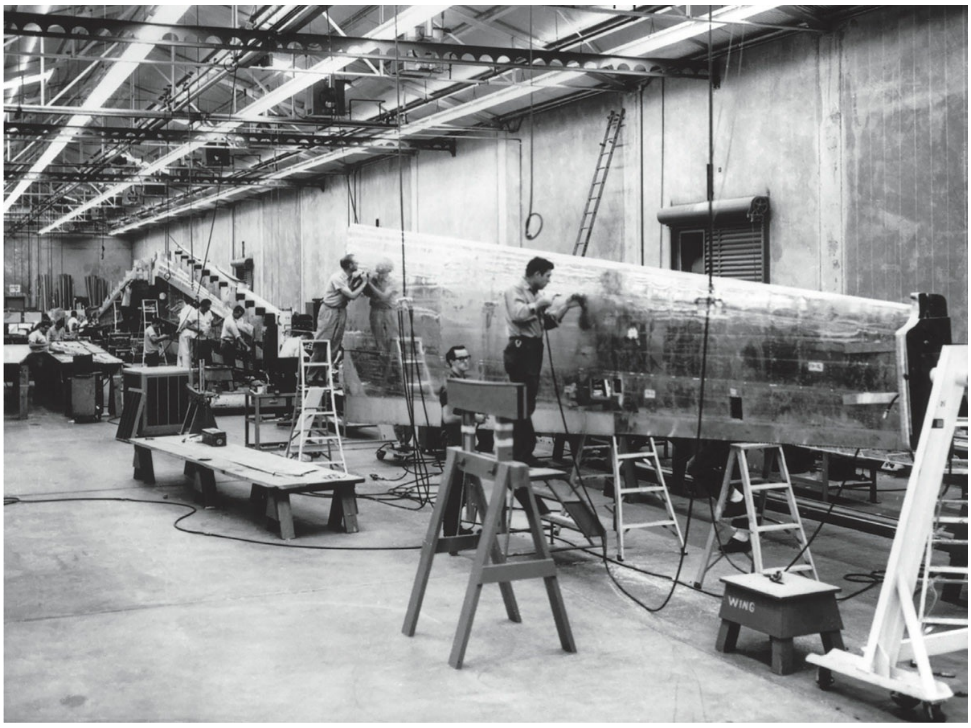
On 1 May 1960, a Soviet surface-to-air missile struck near a U-2 piloted by Francis Gary Powers, while on a reconnaissance mission over Russia. Powers was sentenced to ten years in a Soviet labor camp on 17 August 1960, but would be released two years later in exchange for spy Rudolph Abel.

The U-2, however, would continue to be a critical asset for US intelligence agencies, especially during the Cuban Missile Crisis. It was a U-2 manned by Major Richard Heyser that captured photos of Soviet missile installations in western Cuba on 14 October 1962, revealing that the Russians were capable of launching a nuclear strike against the United States.

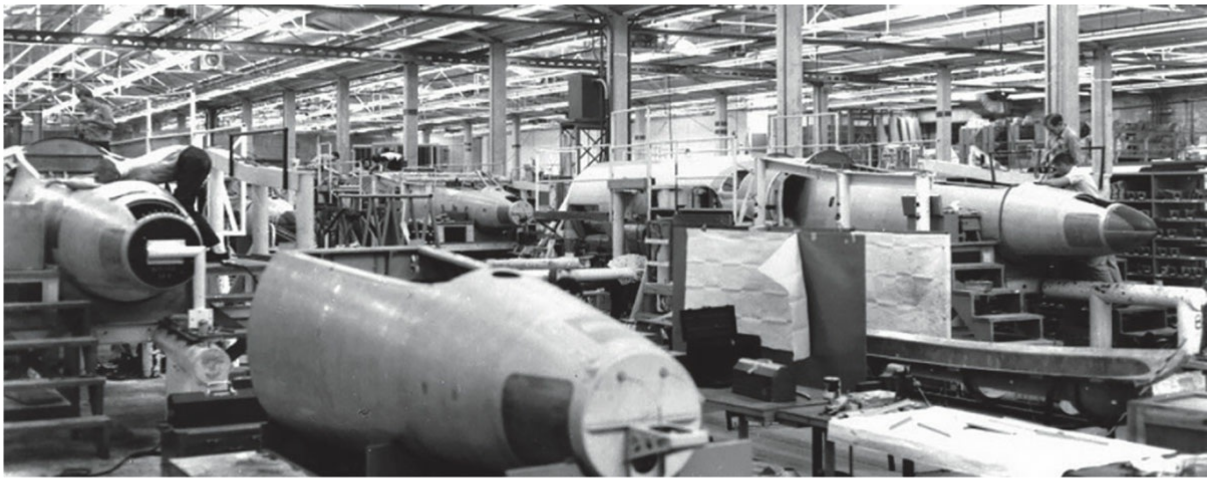
Initially projected to have an operational life of just two years, the U-2 would go on to see service in every subsequent American war, while showing remarkable versatility as a non-military aircraft.

When equipped with a wide variety of sensors, the U-2 has morphed into everything from a high-tech National Aeronautics and Space Administration (NASA) platform for conducting physics experiments to a high-altitude tool for tracking the migration of destructive spruce bark beetles through the forests of Alaska.

Today, U-2s are used as aerial eavesdropping devices; U-2s survey dirt patterns for signs of makeshift mines and improvised explosive devices (IEDs) over Iraq and Afghanistan, making these dynamic high-flyers as effective today as they were nearly seven decades ago.

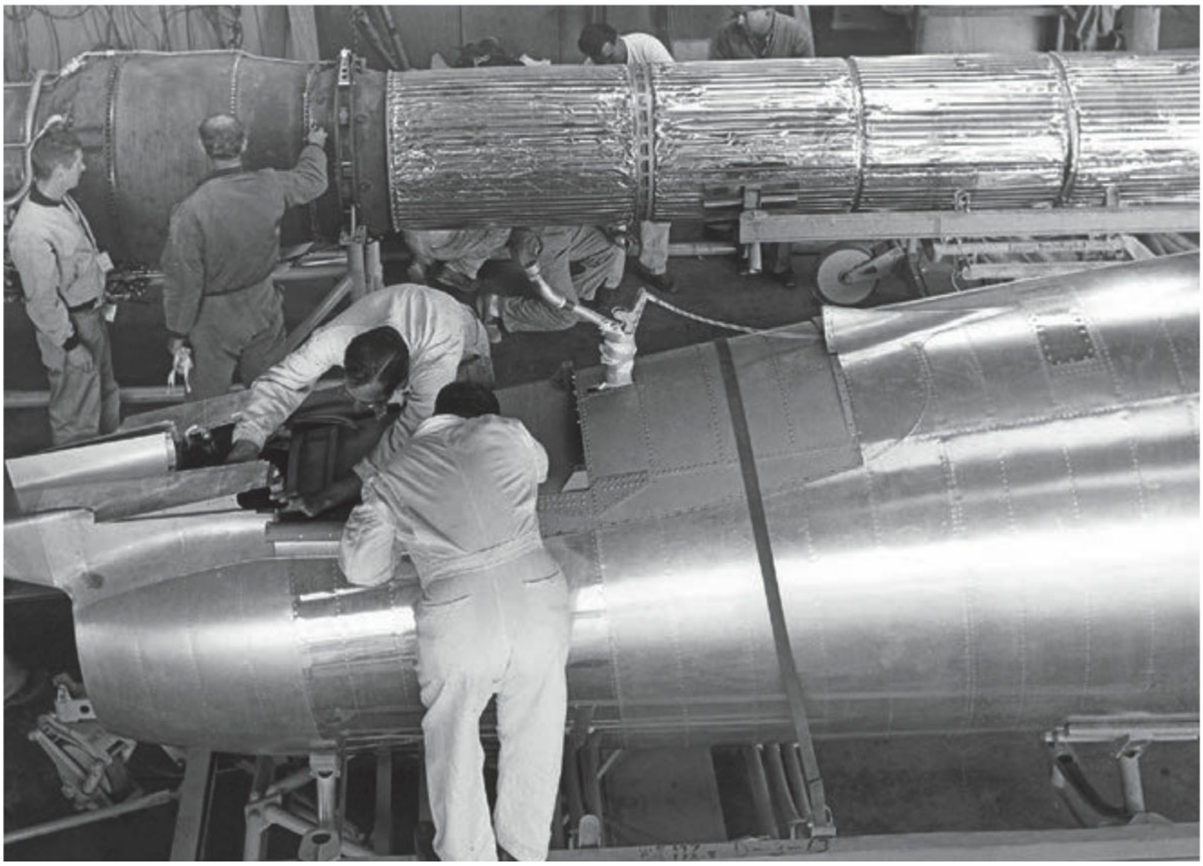


The Skunk Works production team is seen building up the wing set for the U-2A at its secret production facility in Oildale, near Bakersfield, CA. (Author's collection)

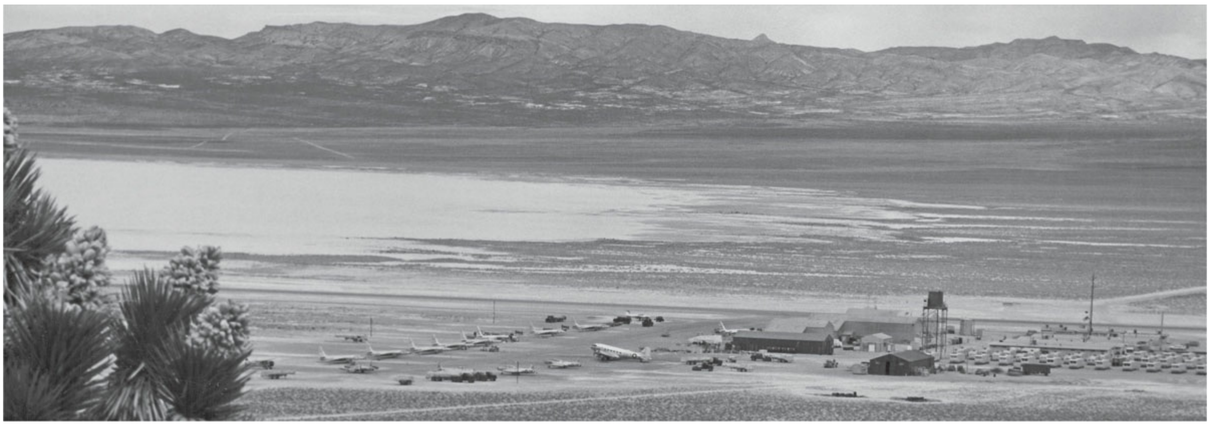


Production buildup of the nose section of the early U-2As at the Oildale facility. (Author's collection)

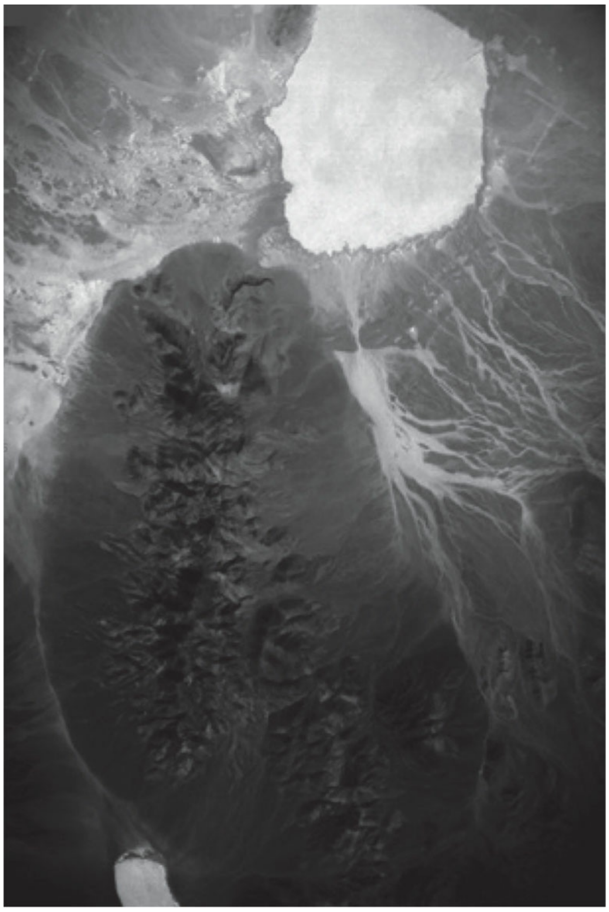
An aerial view of the home of the original U-2 production facility in Oildale, CA
(Author's collection)

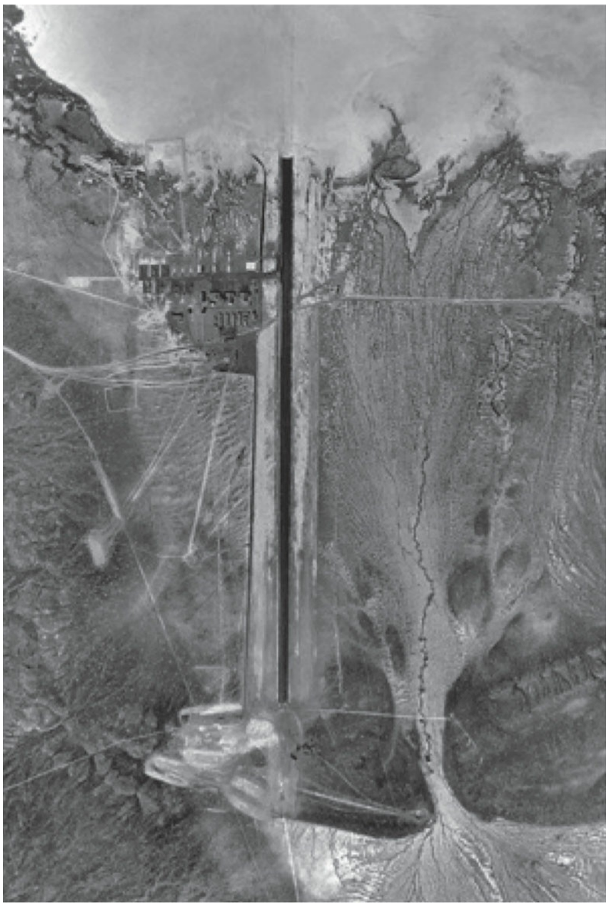


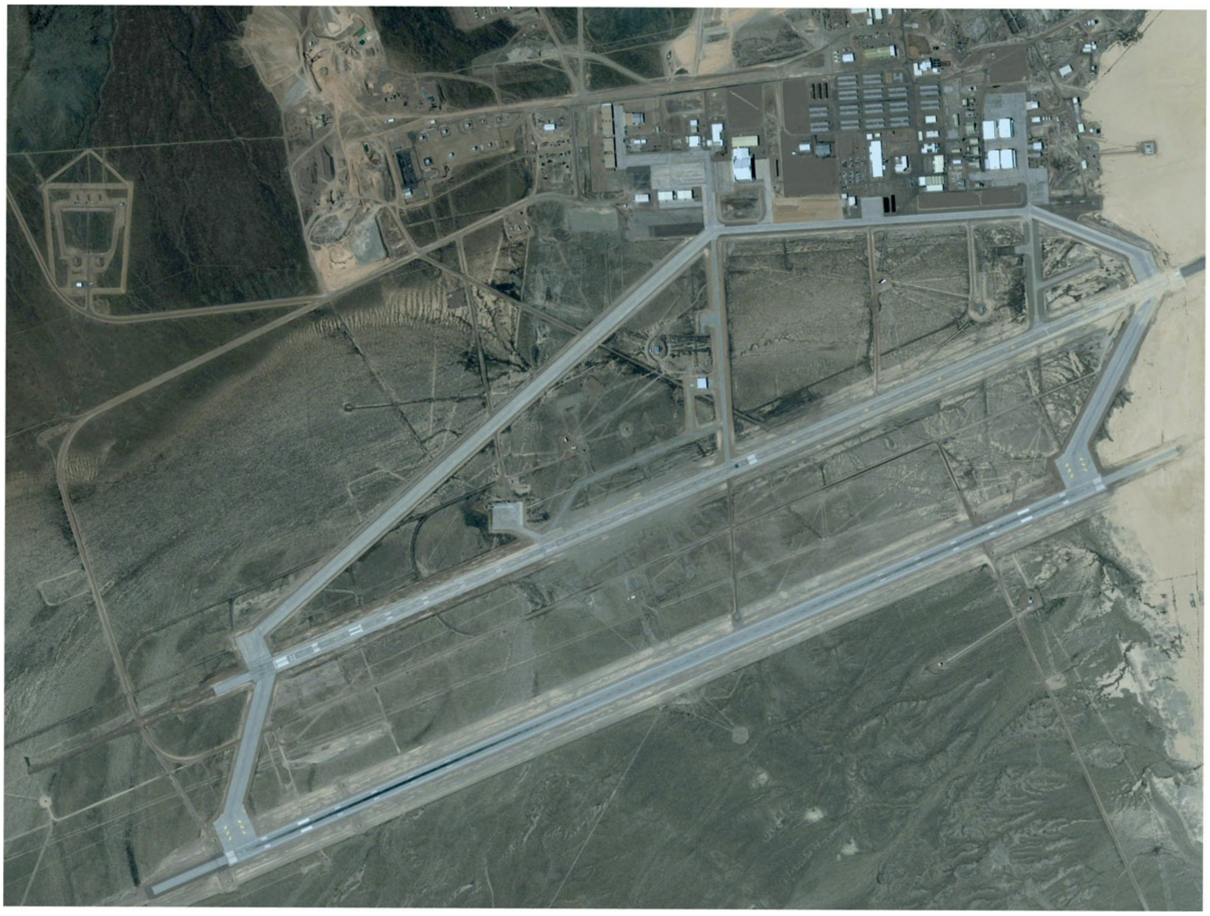
Lockheed technicians work on the aft fuselage of the U-2A with its original Pratt & Whitney J57-P-37 in the background. (Author's collection)



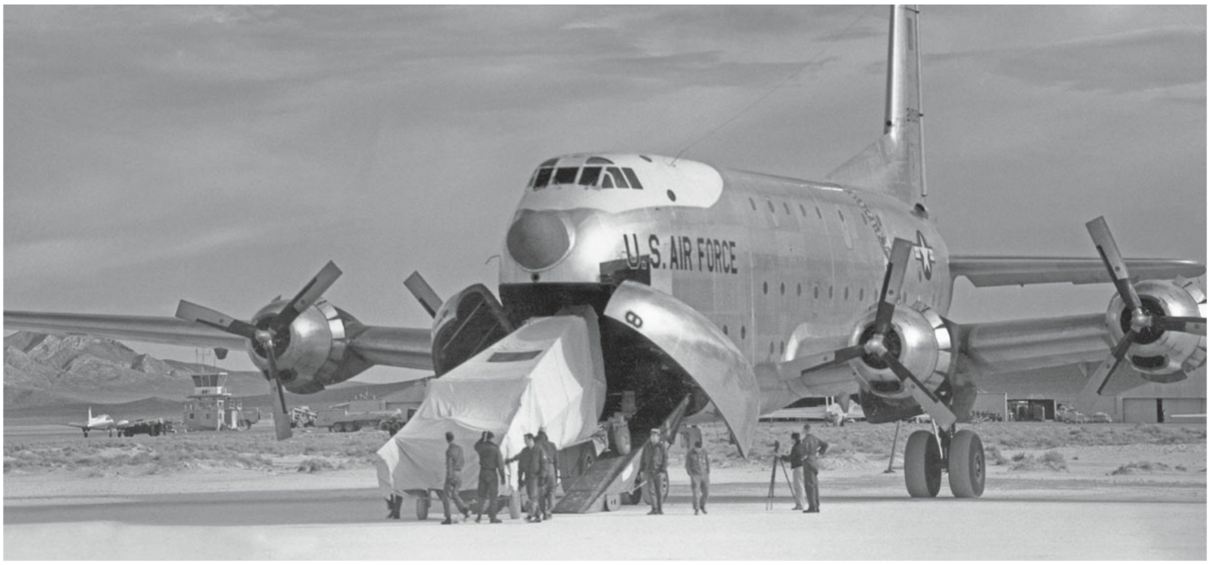
To all who have never set foot in this place, it is truly in the middle of nowhere. Kelly Johnson commented to Tony LeVier after they had landed there for the first time that he thought Area 51 was too remote. (CIA via Lockheed Martin)







The evolution of the place that doesn't exist, Area 51, NV, from a dry lake bed with nothing for miles around to the massive place it is today. (USGS)

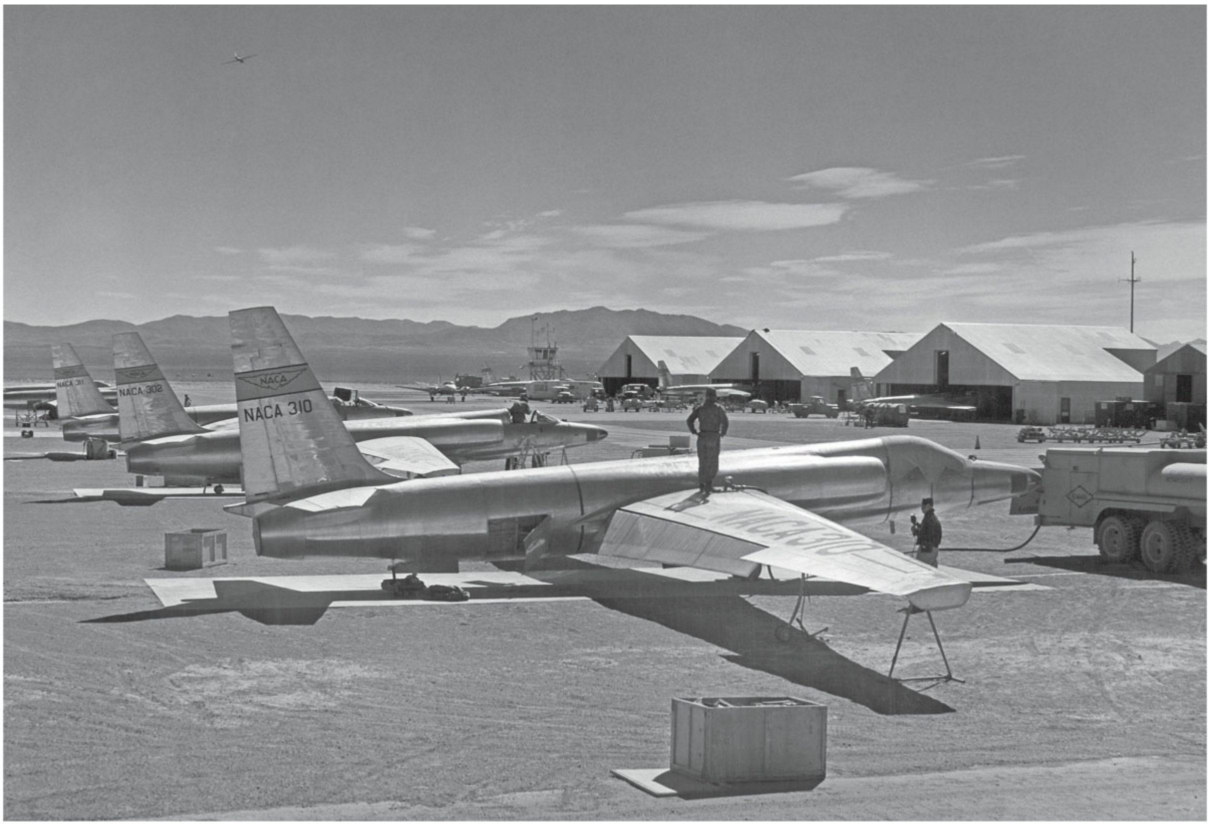


A U-2A is loaded into an Air Force C-124B Globe Master II as the USAF prepares to move operational U-2s to Korea. (CIA via Lockheed Martin)

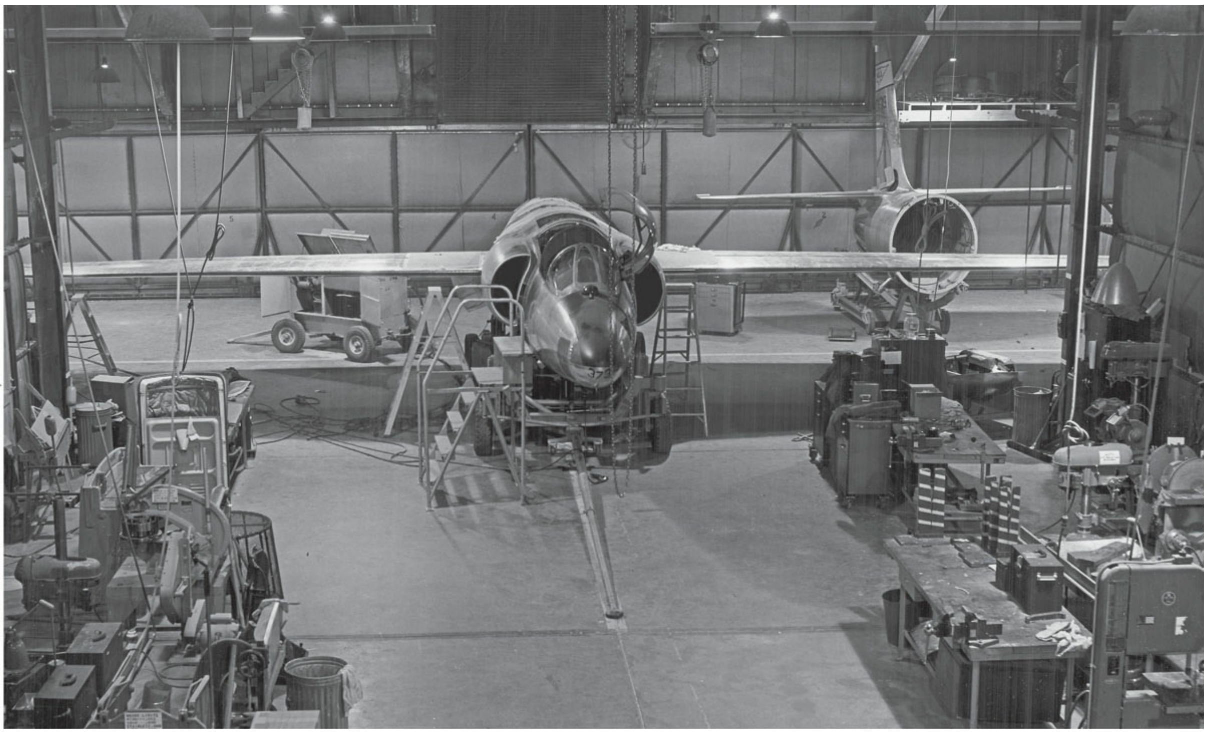
Not what you would call living the "high life" at the temporary living trailers at the test site. (Lockheed Martin)

NELLIS BOMBING AND GUNNERY RANGE
RESTRICTED AREA
NO TRESPASSING
BEYOND THIS
POINT
PHOTOGRAPHY IS
PROHIBITED
WARNING
U.S. Air Force Installation

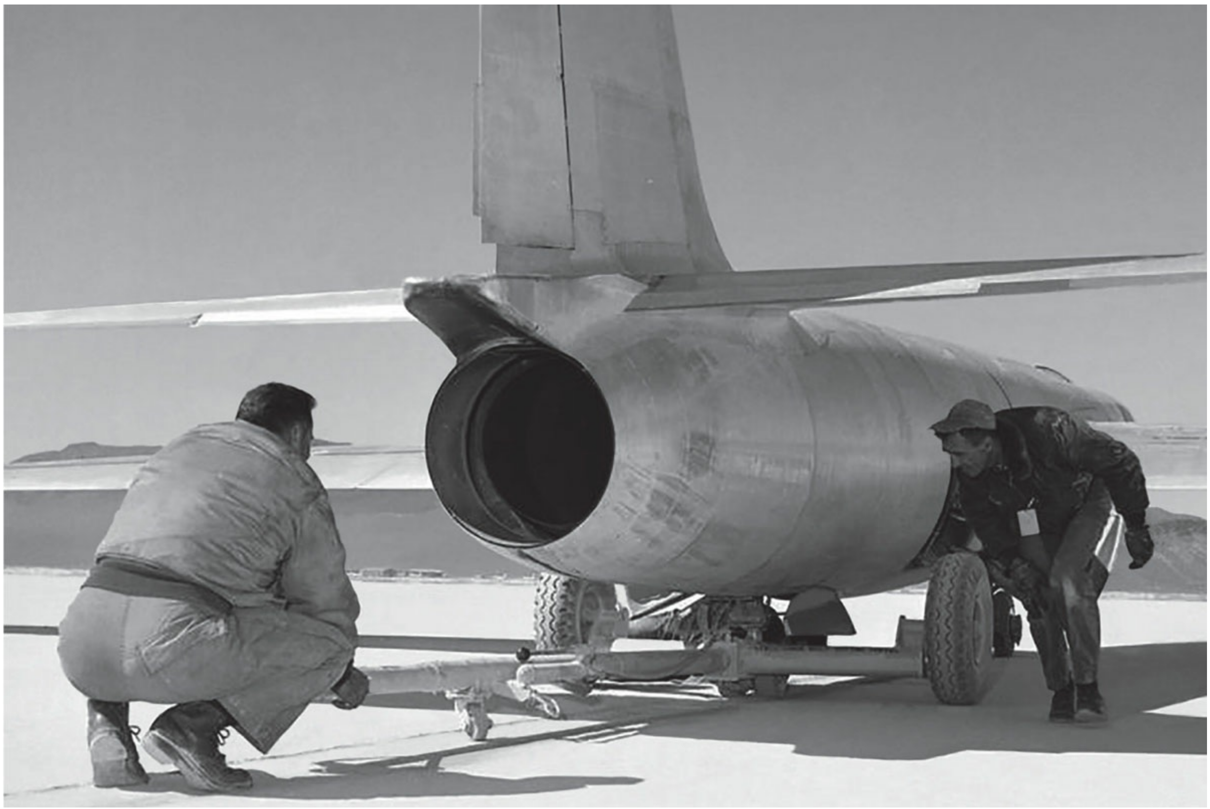
A warning sign with the words "Use of Deadly Force Authorized" on the back road to Area 51. (James C. Goodall)



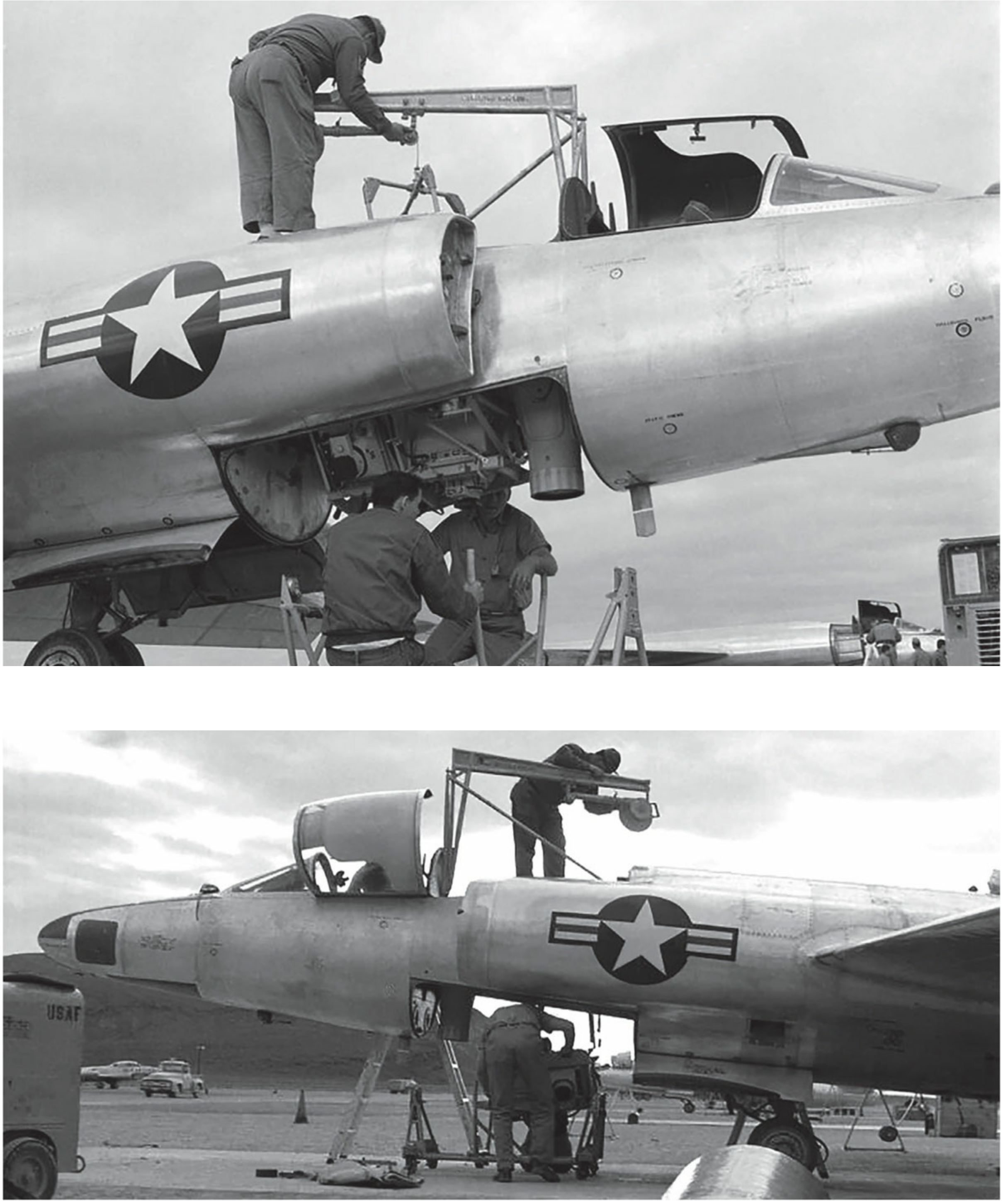
On the ramp at Area 51 are at least seven U-2As with one in the pattern over Groom Dry Lake in this photo. (CIA via Lockheed Martin)



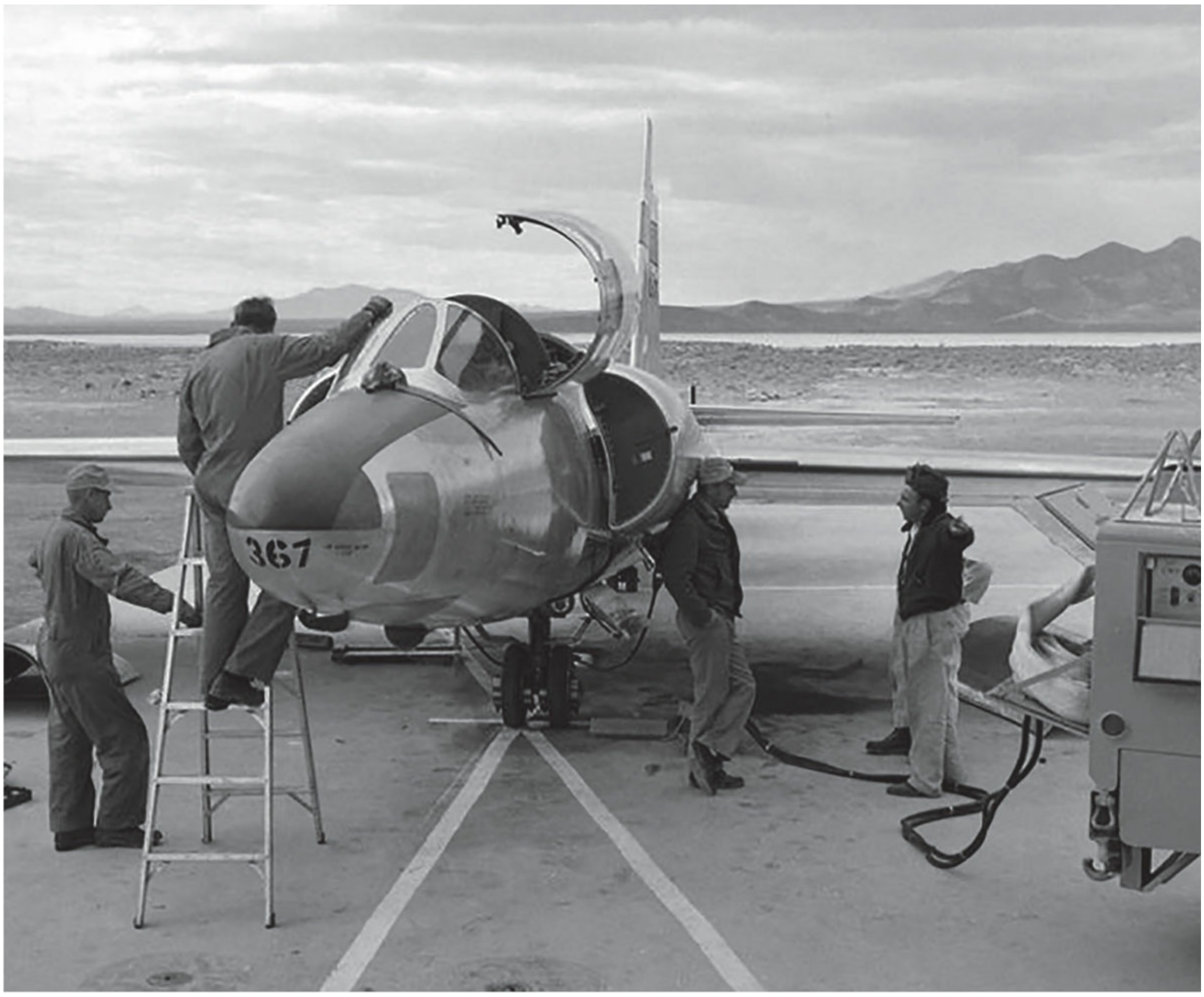
Once the U-2s arrived at the test site, they had to be put back together. Each U-2 was delivered via an Air Force C-124B Globe Master II and went directly into one of the three dedicated U-2 hangars for reassembly and systems installation and checkout. (CIA via Lockheed Martin)



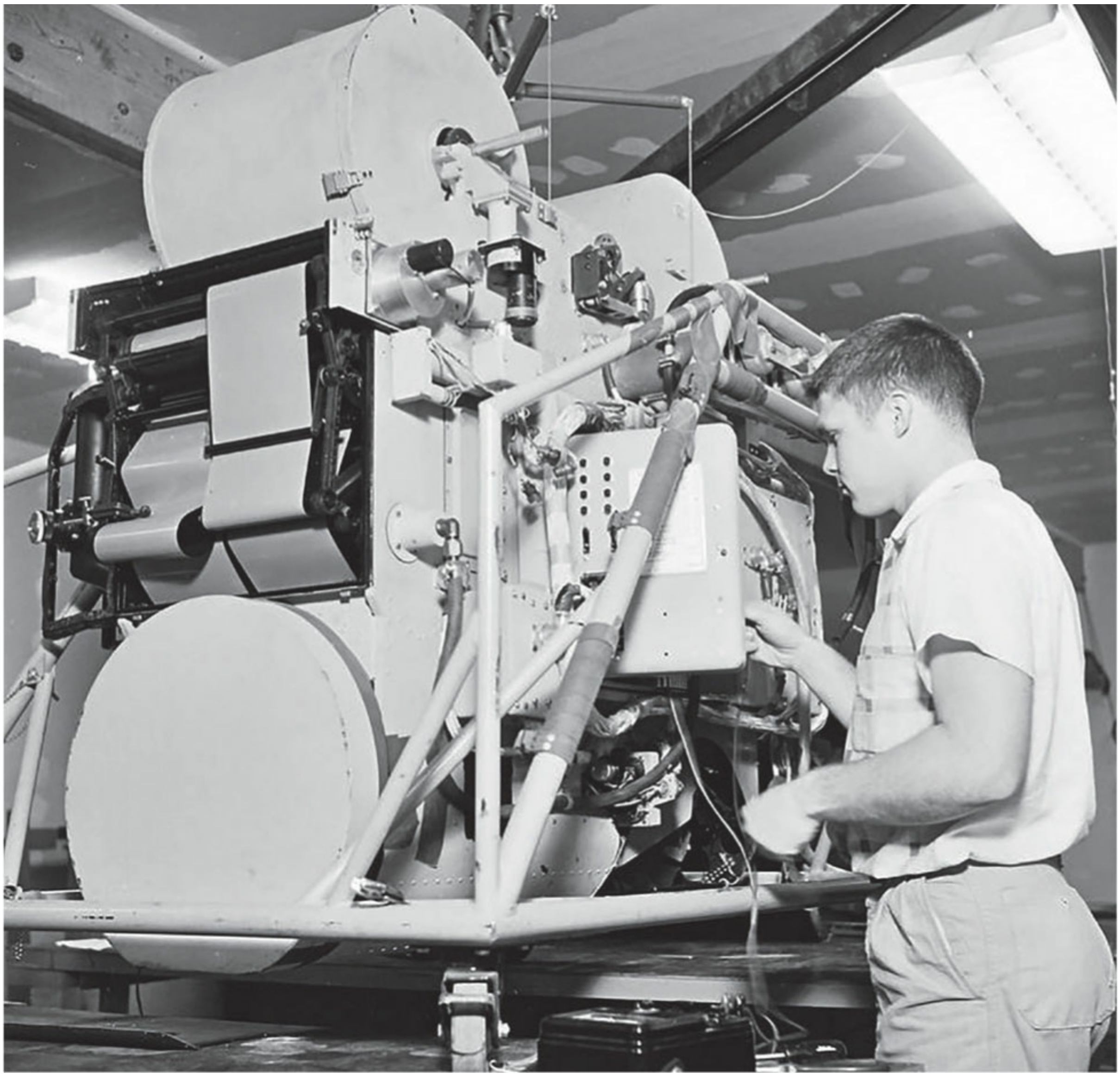
Ground crew and crew chief check out the towing fixture as they recover the U-2 after a test flight. During early flights, the droppable outrigger "pogo" wings wheels were pinned in place. (CIA via Lockheed Martin)



Air Force camera technicians seen loading the Type B camera into the Q-bay of the U-2A. The camera was uploaded from the bottom of the open Q-bay via a lift fixture that hooked into the upper hatch attachment points. (USAF)



U-2A BuNo number 367 was assigned the serial number 56-6700 and was lost on 29 May 1975 near Winterberg, Germany. USAF pilot Robert T. Rendleman survived. (Lockheed Martin)



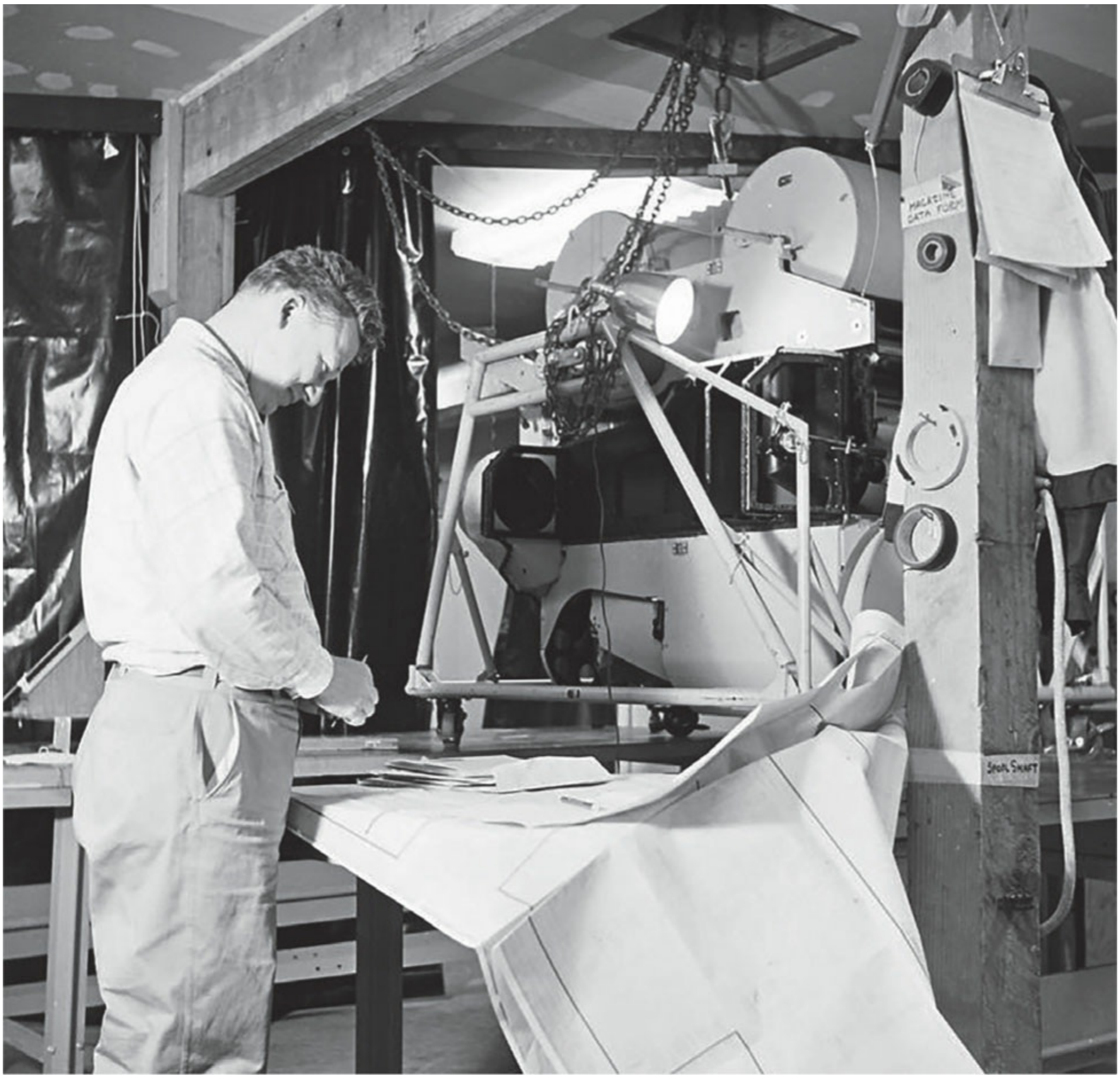
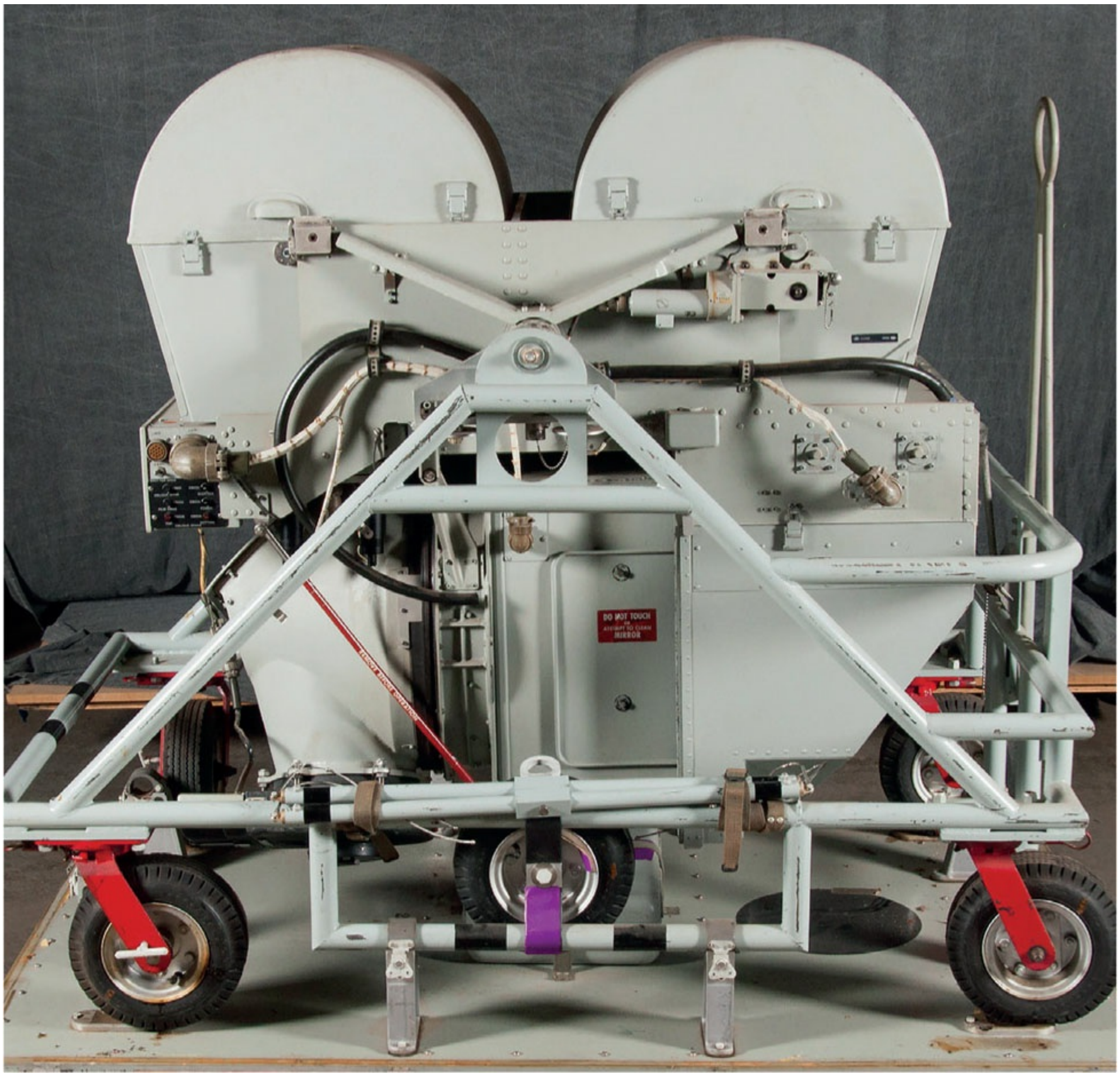

MAGAZINE
DATA FORM
SPOOL SHAFT

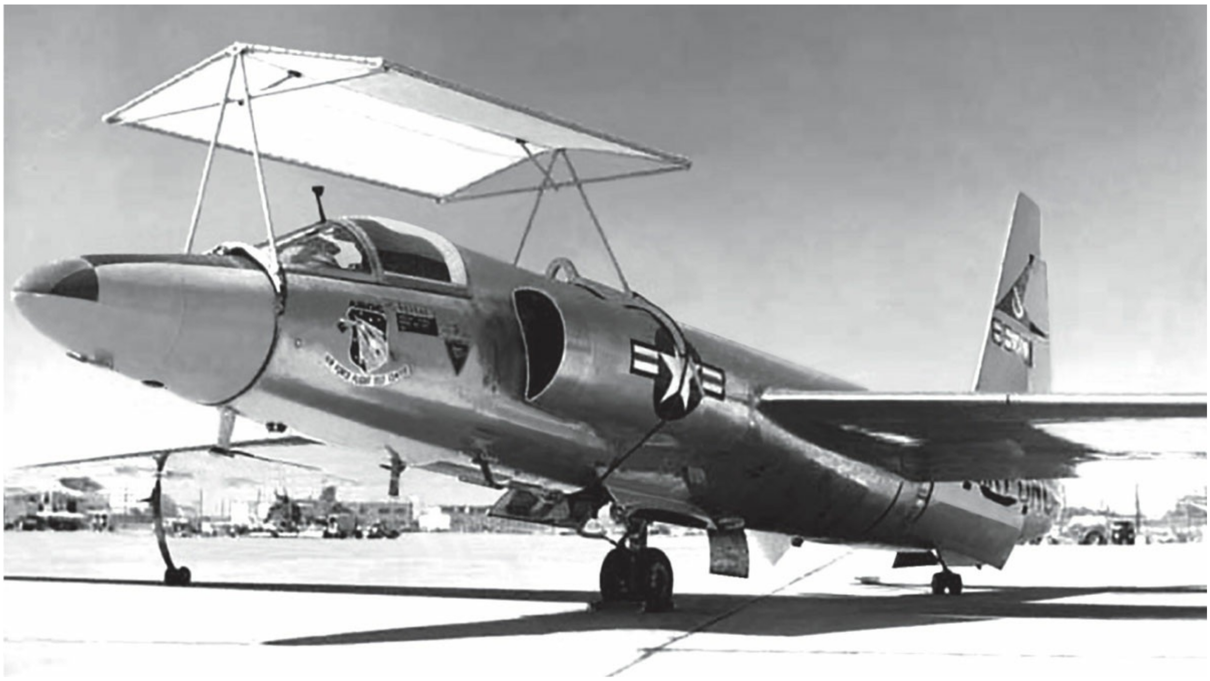
Photo techs check out the Type B camera prior to it being installed in the Q-bay of the U-2. The Type B camera was a workhorse. Its 36in folded optics lens was the highest resolution device of its kind in the world at the time of its debut. (USAF)


DO NOT TOUCH
MIRROR

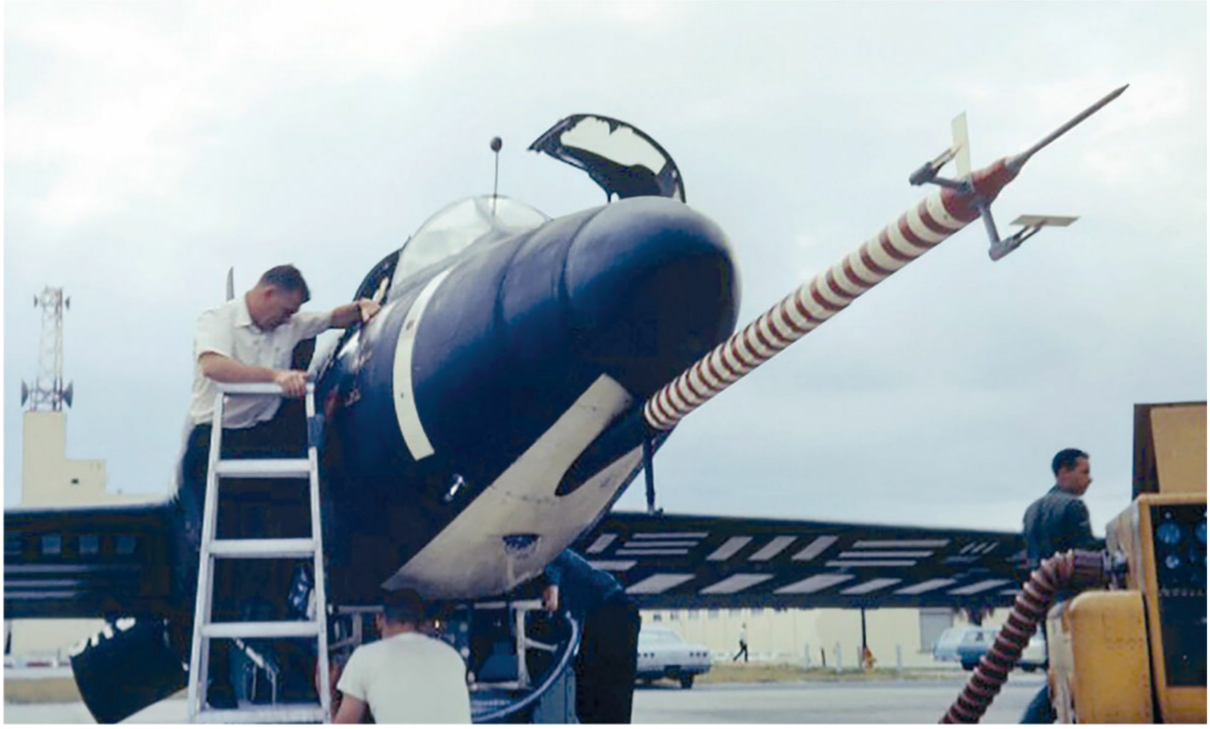
A color walk-around of the U-2's Type B camera. (SASM)

U-2A sporting the National Advisory Committee for Aeronautics (NACA) 308 as it prepares to take off from Groom Dry Lake in early 1956. (CIA via Lockheed Martin)

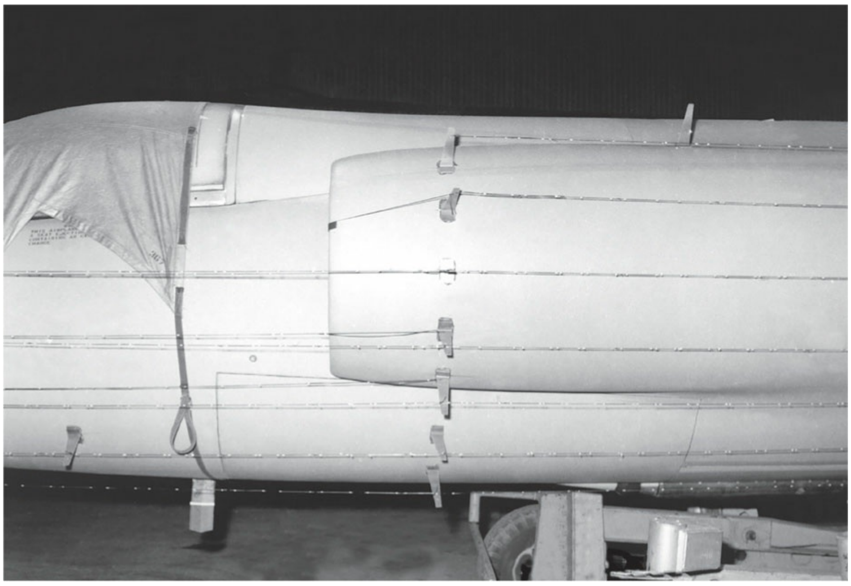
A U-2A is preparing to start its Pratt & Whitney J57-P-37 as the crew chief makes sure the pilot is secure and all "Remove Before Flight" pins have been pulled. (CIA via Lockheed Martin)



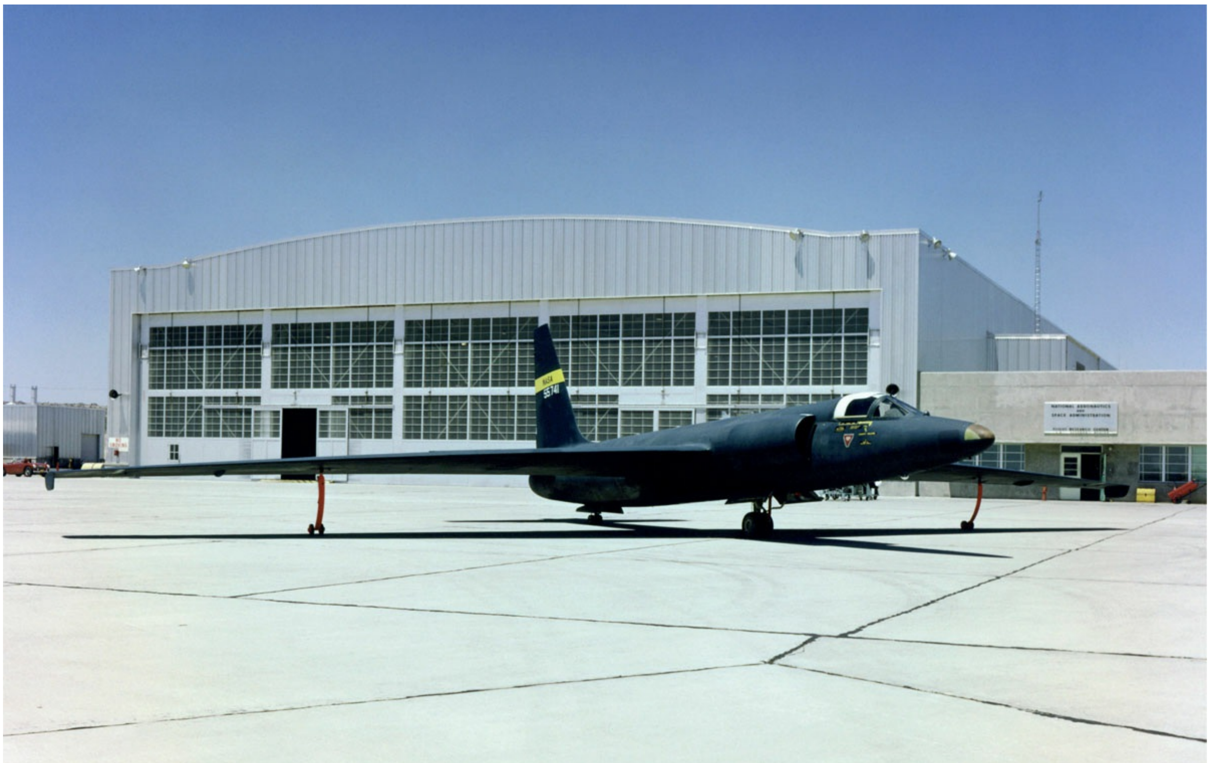
On the ramp at Edwards AFB, this U-2A, 56-6701, was the very first U-2 assigned to the AFFTC at Edwards. It is shown sporting its now-familiar sun shade as the high desert sun can really heat things up if it is not protected from the sun's rays. (Author's collection)



A single U-2A, 56-6722/389, was modified to the HICAT (High-altitude Clear Air Turbulence) configuration and equipped with a gust-sensing probe under the nose and other associated equipment. (Author's collection)



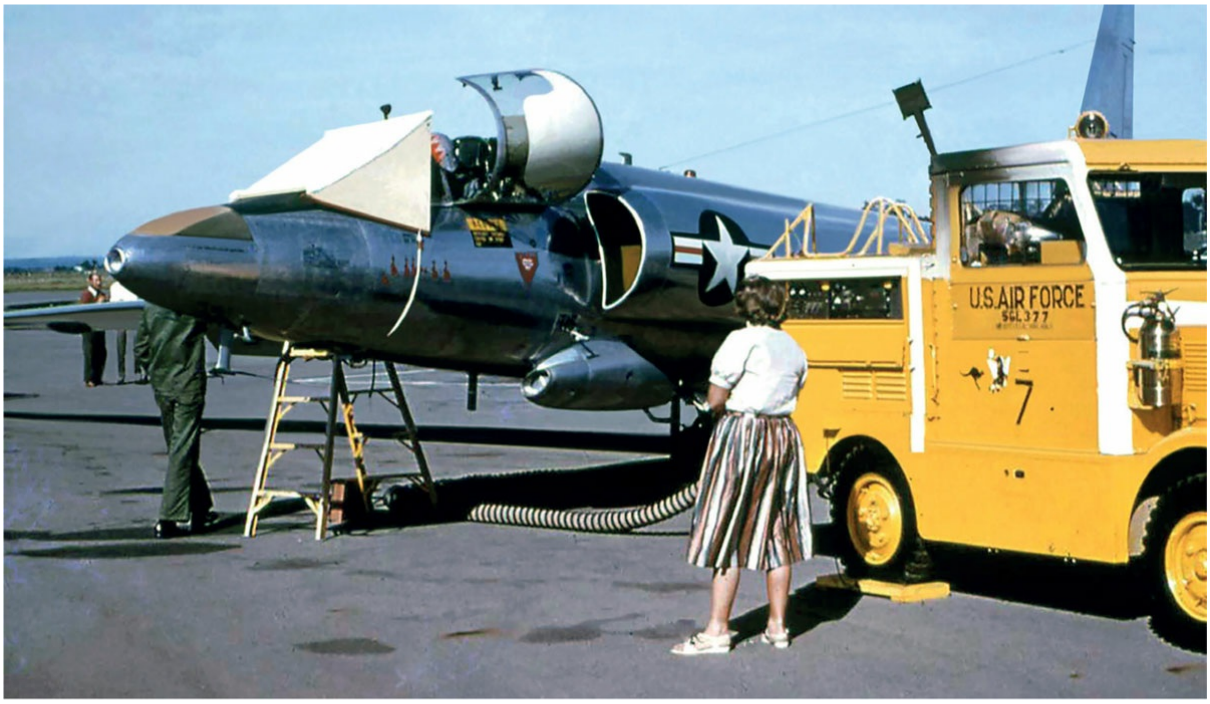
In an attempt to thwart or negate Soviet style VHF type radars, and to make the U-2 harder to track by working to give it a smaller radar cross section, Lockheed experimented with stringing wires across the U-2 with specific distances between wires. (CIA via Lockheed Martin)



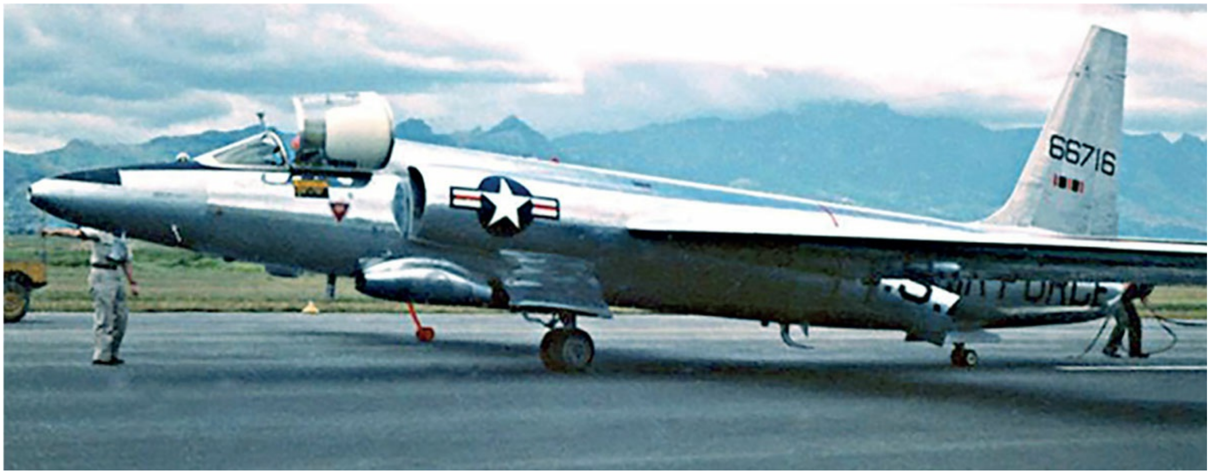
This U-2A was photographed at NASA's Dryden Flight Research Center on 6 May 1960, less than a week after the CIA pilot Francis Gary Powers was shot down over the Soviet Union, with bogus NASA markings. (NASA)

U.S. AIR FORCE
USAF

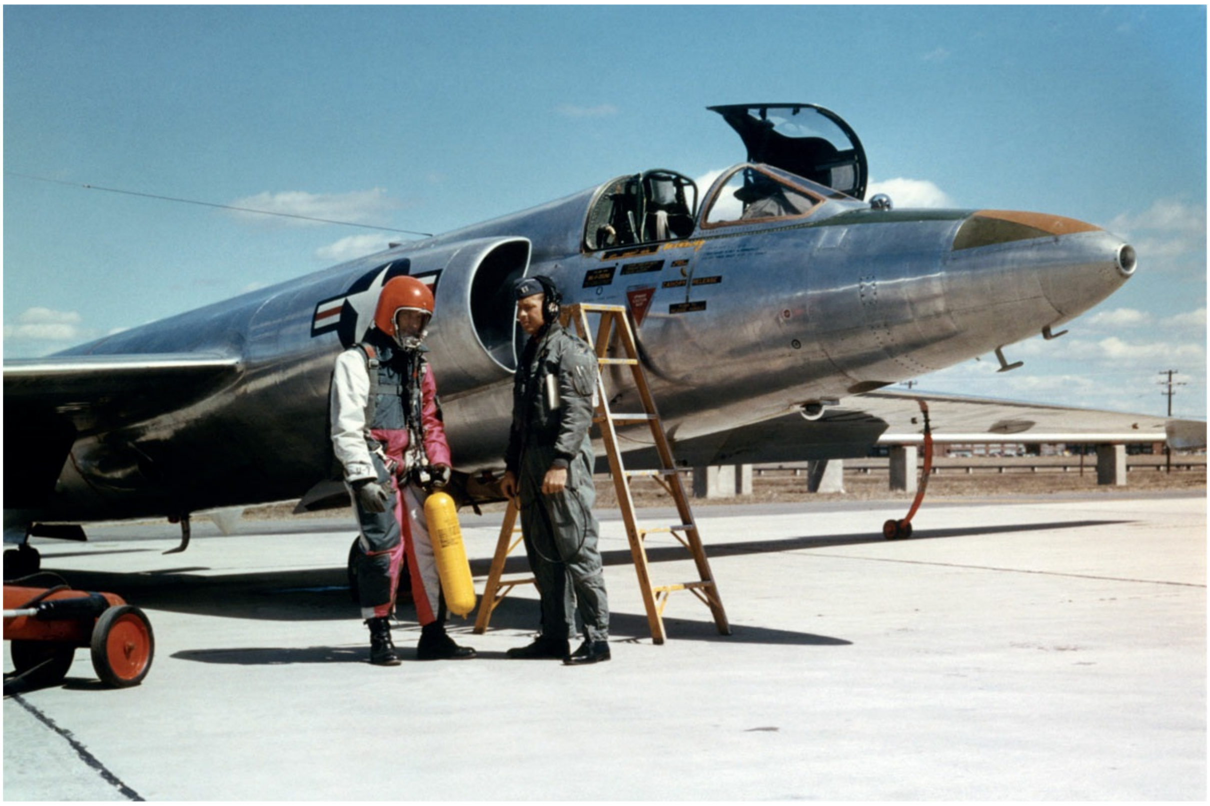
One of the three High-Altitude Sampling Program (HASP)-configured WU-2As, 56-6714, banks hard to the port during a training flight. (Author's collection)



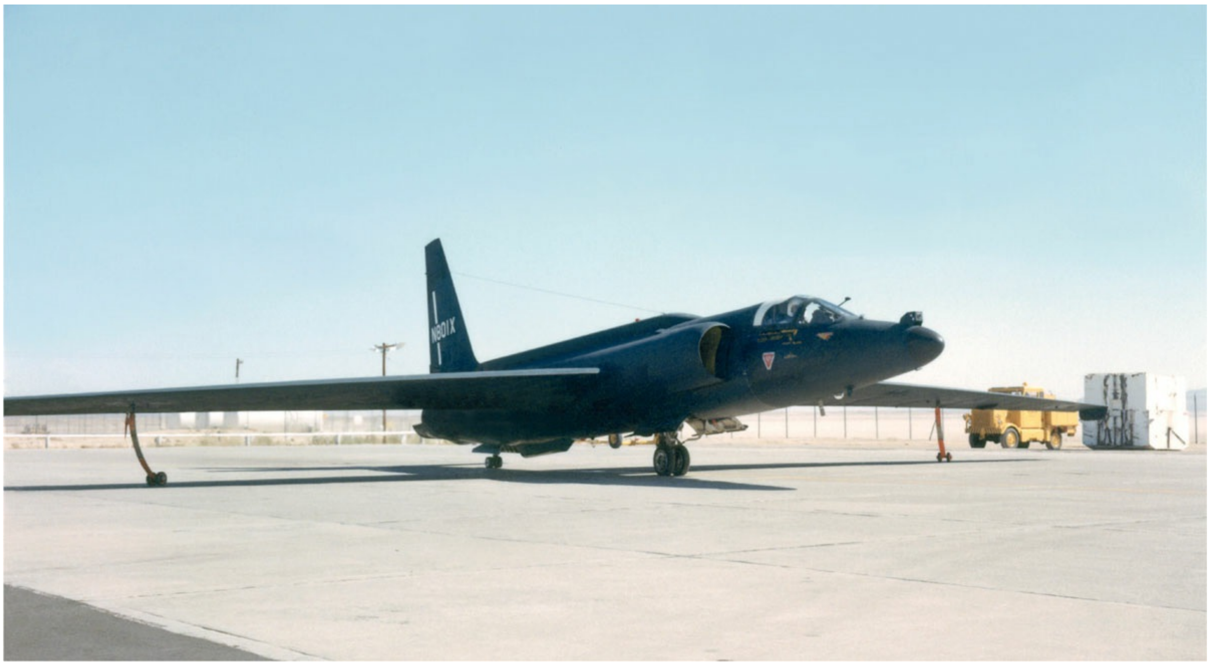
In this image, the HASP WU-2A 56-6714 has a sunshade covering the windscreen to allow instrument calibration and a better view of the Q-bay's particulate sampling equipment. Just visible in the opening of the particulate sampler is a valve that regulates the amount of airflow entering the sampler. (Author's collection)



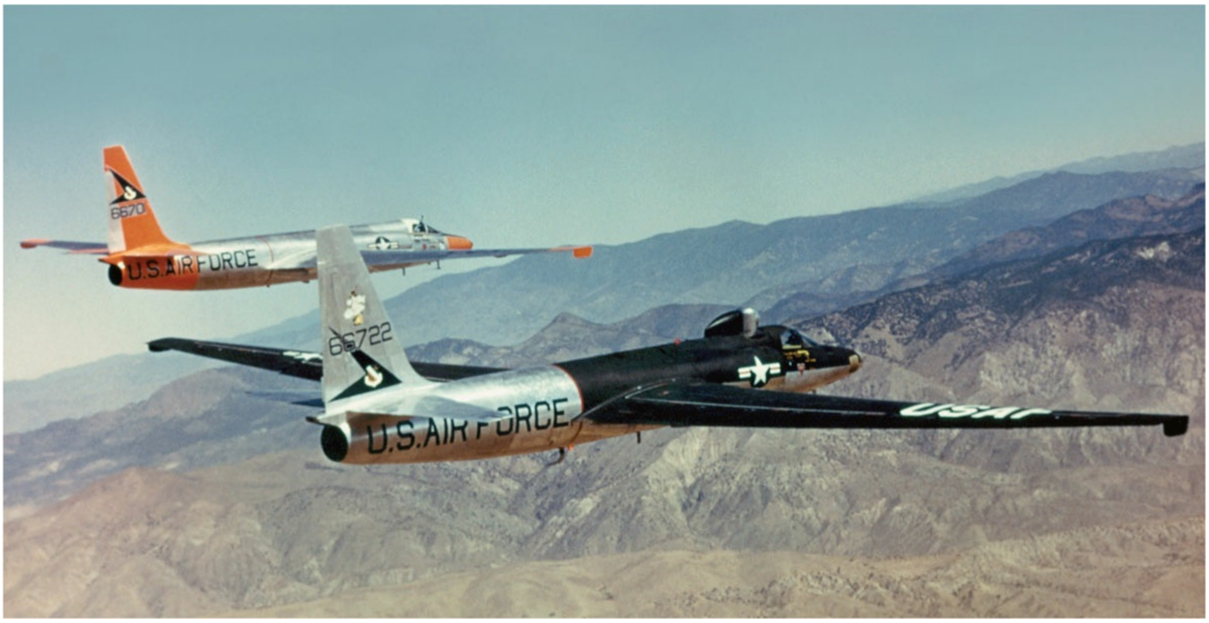
Side view of one of the three WU-2As modified for HASP sampling missions. WU-2A 56-6716 was photographed after it arrived in Fiji en route to Australia in 1961. (Author's collection)



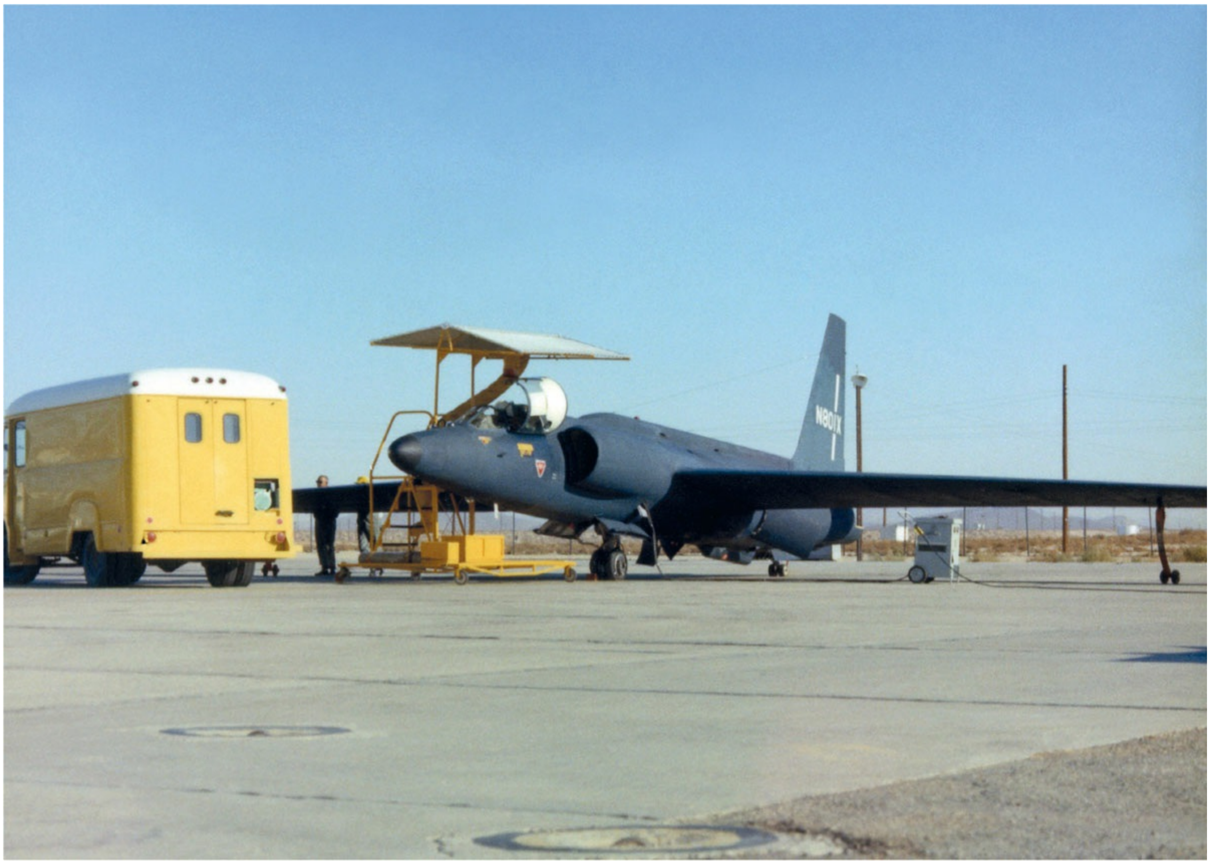
The third WU-2A HASP U-2, 56-6715; the detachment commander is speaking to the pilot just prior to a HASP flight. (Author's collection)



A U-2A being towed back to its hangar at Edwards AFB North Base after a training flight. Originally procured as Lockheed U-2A, 56-6681, this U-2A was converted to U-2G configuration for testing aboard US Navy aircraft carriers in the early 1960s; it carried the FAA registration tail code of N801X. (Lockheed Martin)



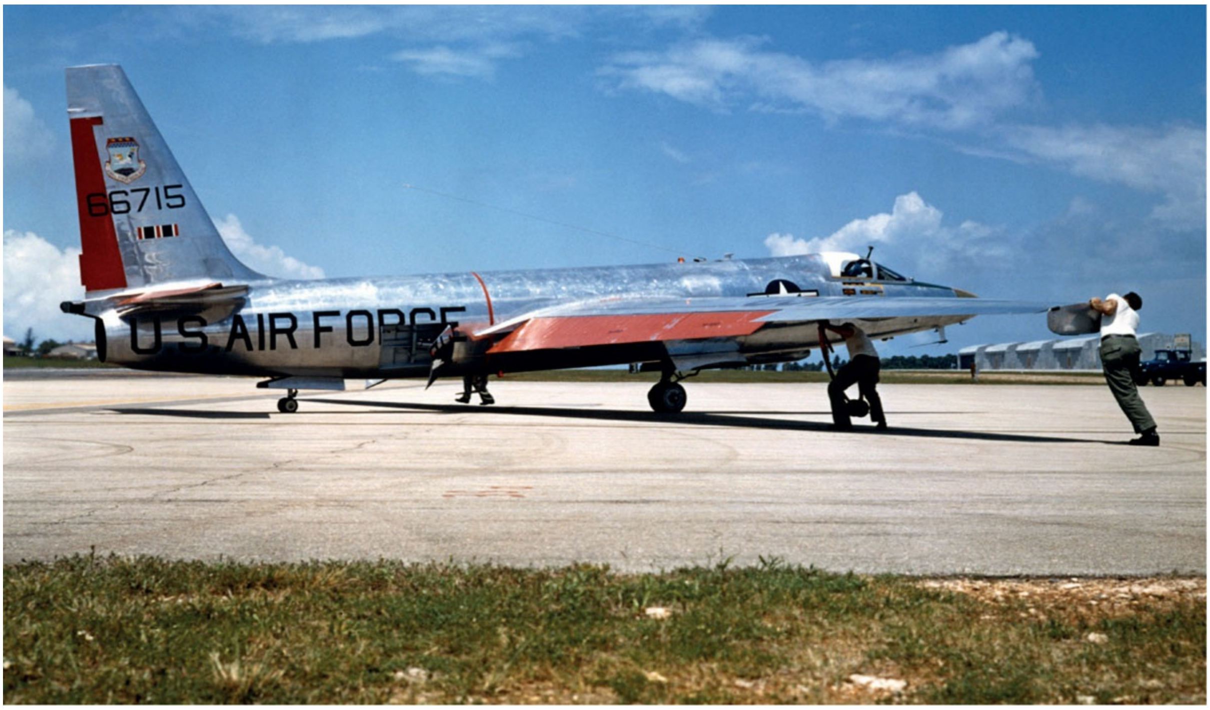
Two of the 6512th Test Wing U-2s, the only U-2D, 56-6722, and U-2A 56-6701 fly in formation for a photo shoot. Note the "Smokey Joe" patch on the tail of 56-6722. (Lockheed Martin)



The U-2A carrying the civil registration N801X is preflighted at Edwards AFB North Base. (Lockheed Martin)

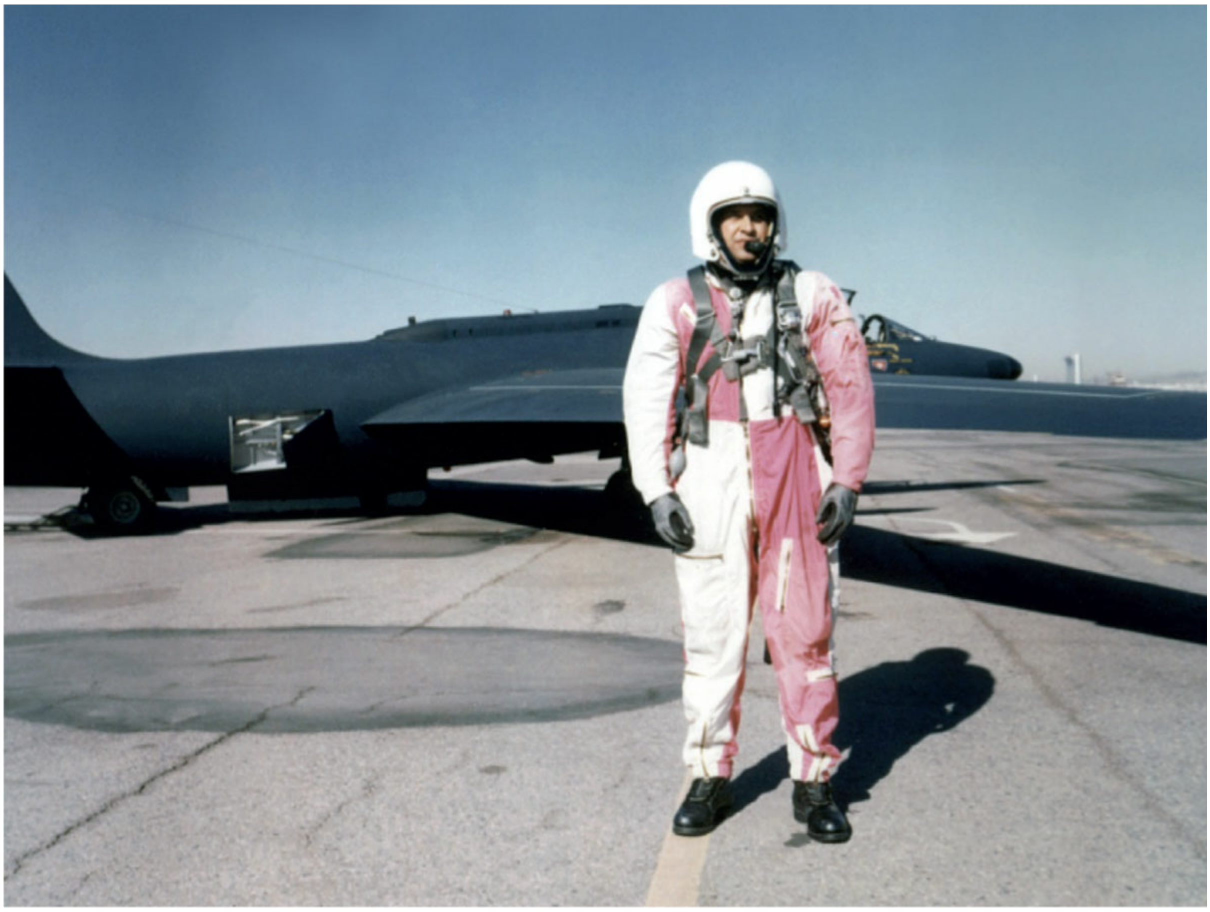
US AIR FORCE

A U-2A, 56-6703, in all-natural metal heads to the stars. This U-2A was delivered to the Air Force at Area 51 in April 1957. (Author's collection)

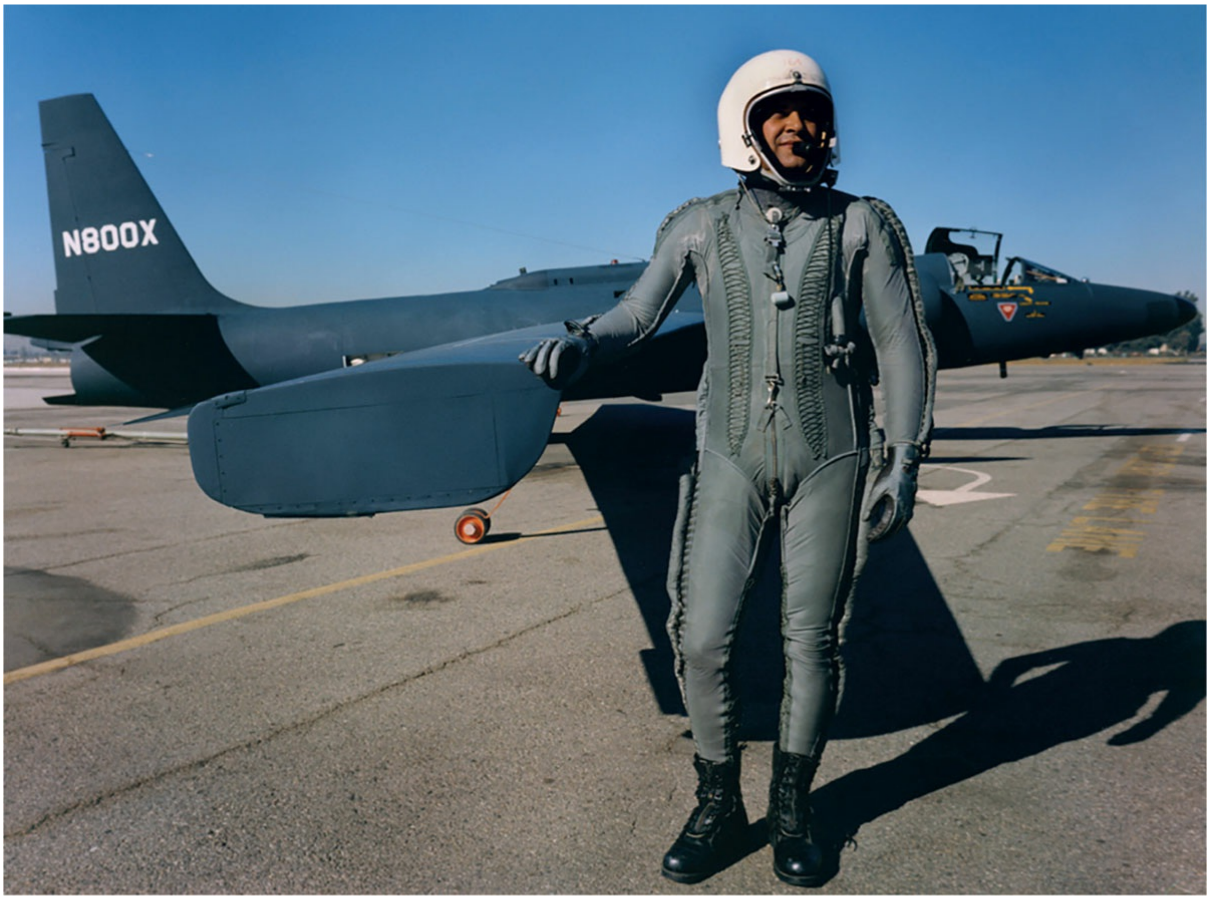


A beautiful color shot of this Edwards-based U-2A, 56-6701, was taken on 20 May 1962. Owing to its mission of testing and research, the Edwards U-2s were usually the most colorful. (Lockheed Martin)

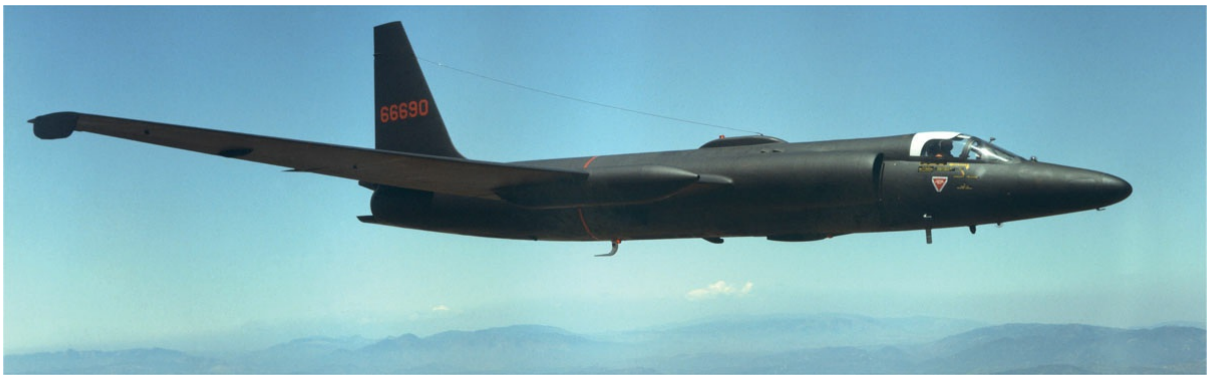
The mastermind of the Lockheed Skunk Works, the Head Skunk, Kelly Johnson, stands in front of one of his most famous designs, the Dragon Lady, also known as the U-2. (Lockheed Martin)



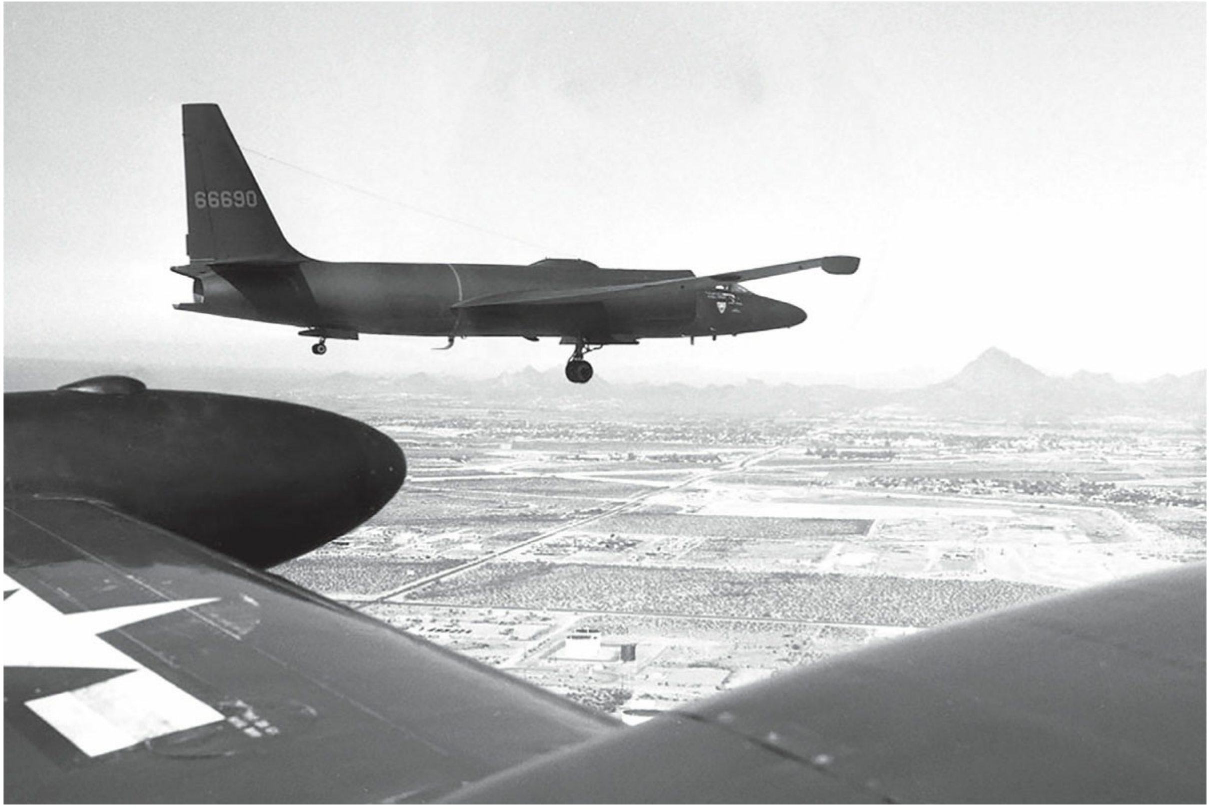
This image shows the high visibility outer suit worn during testing to make it easier to locate the pilot if and when the pilot had to bail out. (Author's collection)



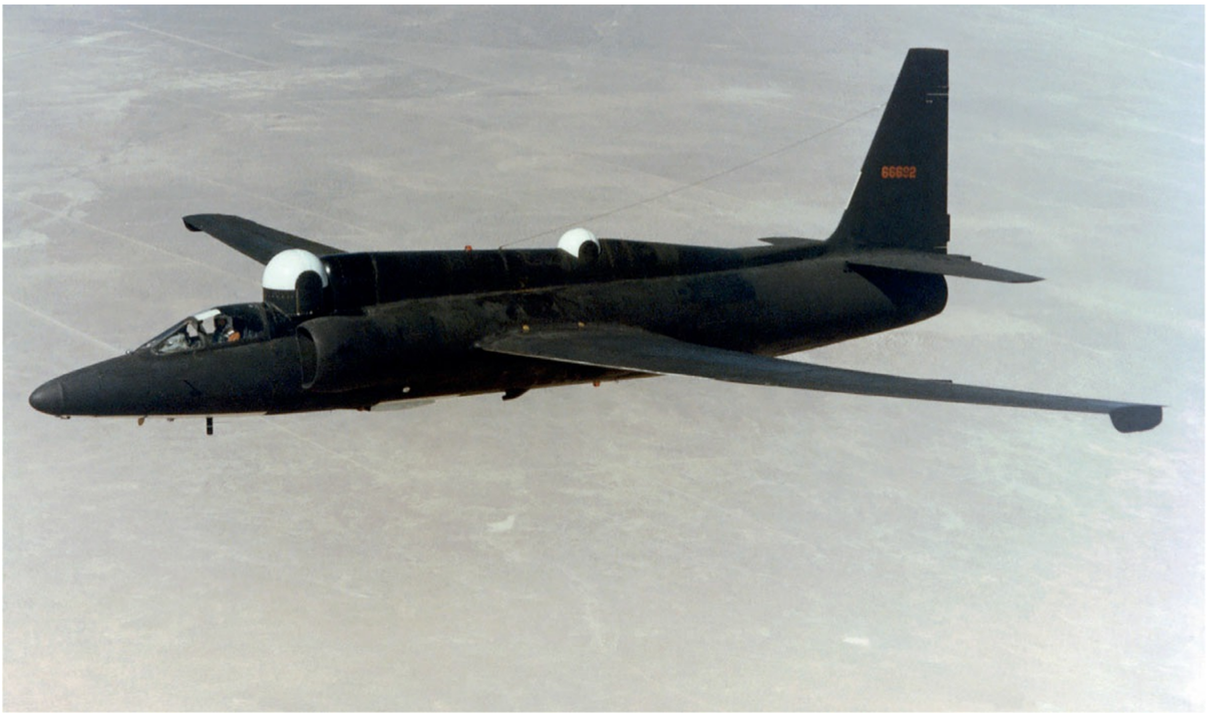
CIA/Lockheed pilot Francis Gary Powers sports the early-style MC-2-type high-altitude partial pressure suit, standing in front of a U-2F, N800X. (Author's collection)



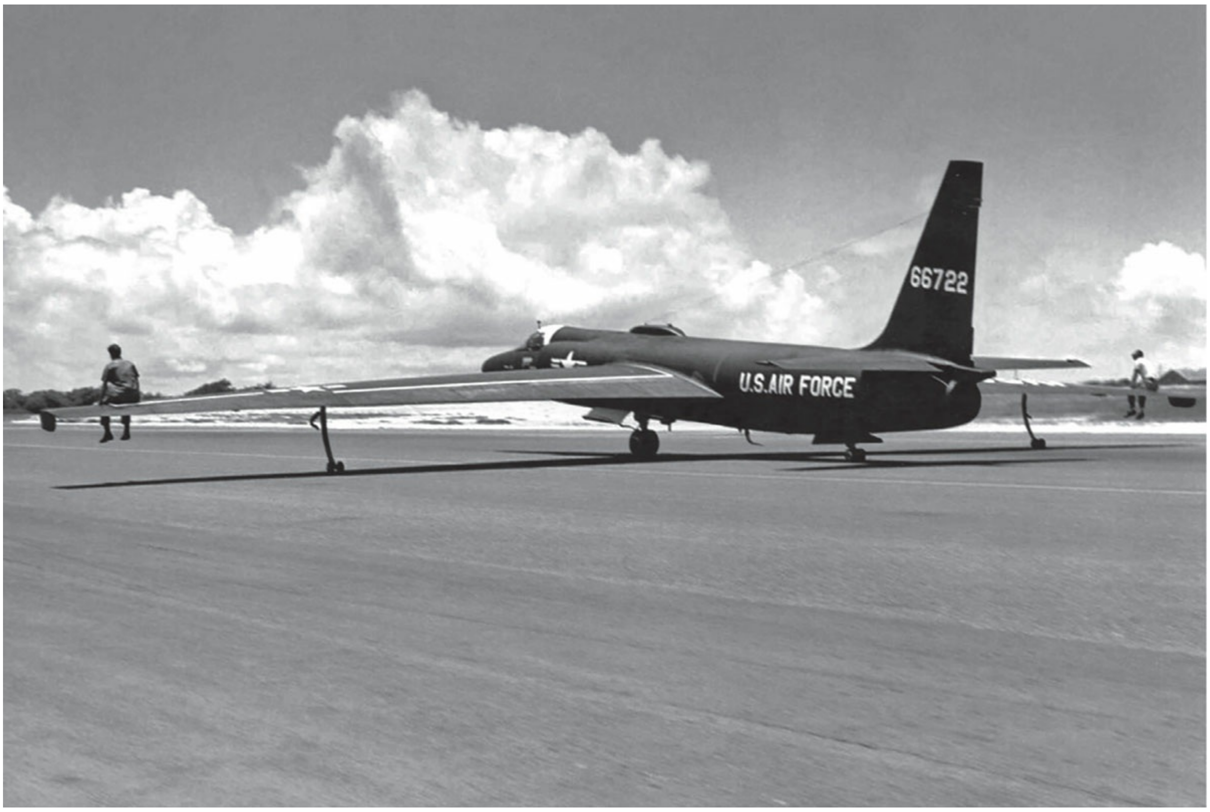
This image is of U-2A 56-6690/357 cruising over the San Gabriel Mountains just north of Los Angeles. 6690 was delivered to the CIA on 21 September 1956 and was lost during a training flight on 19 December 1956. (Lockheed Martin)



U-2A 56-6690/357, photographed from a chase plane as it heads for a landing approach at Edwards North Base. (Author's collection)

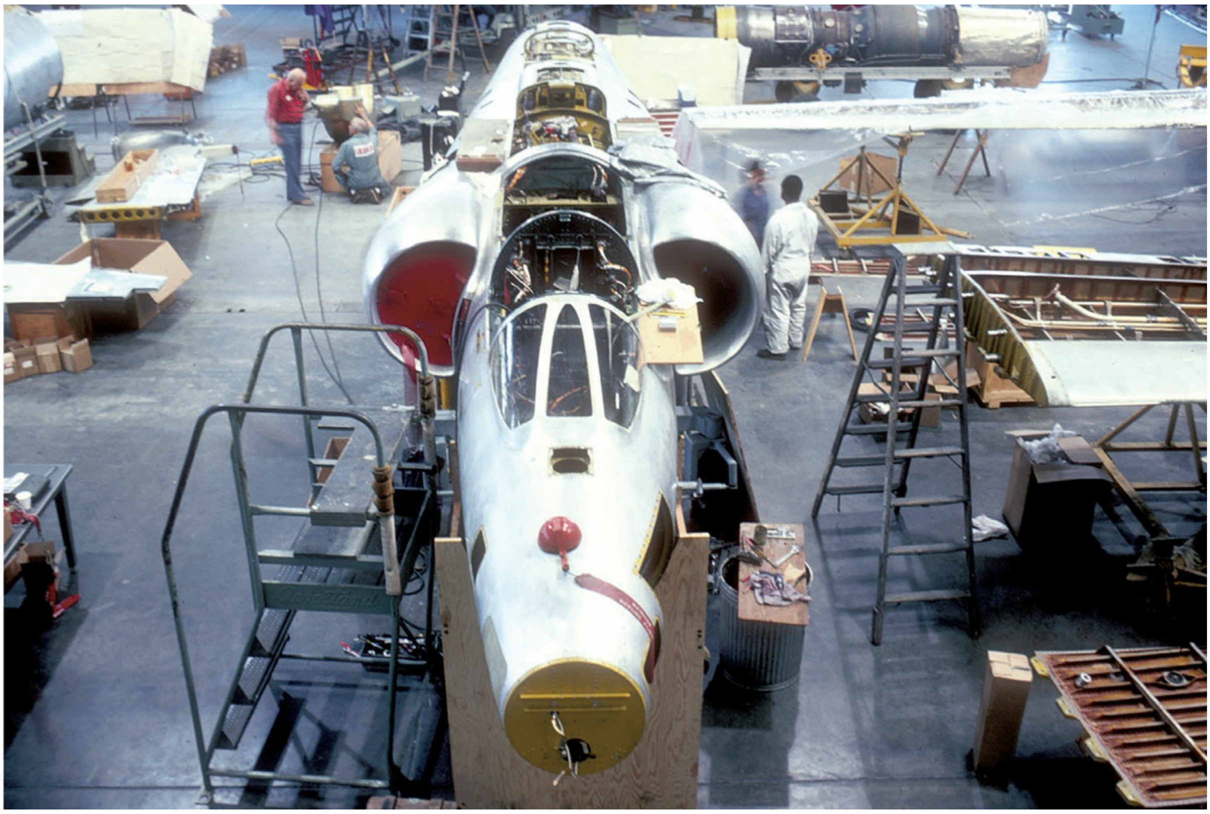


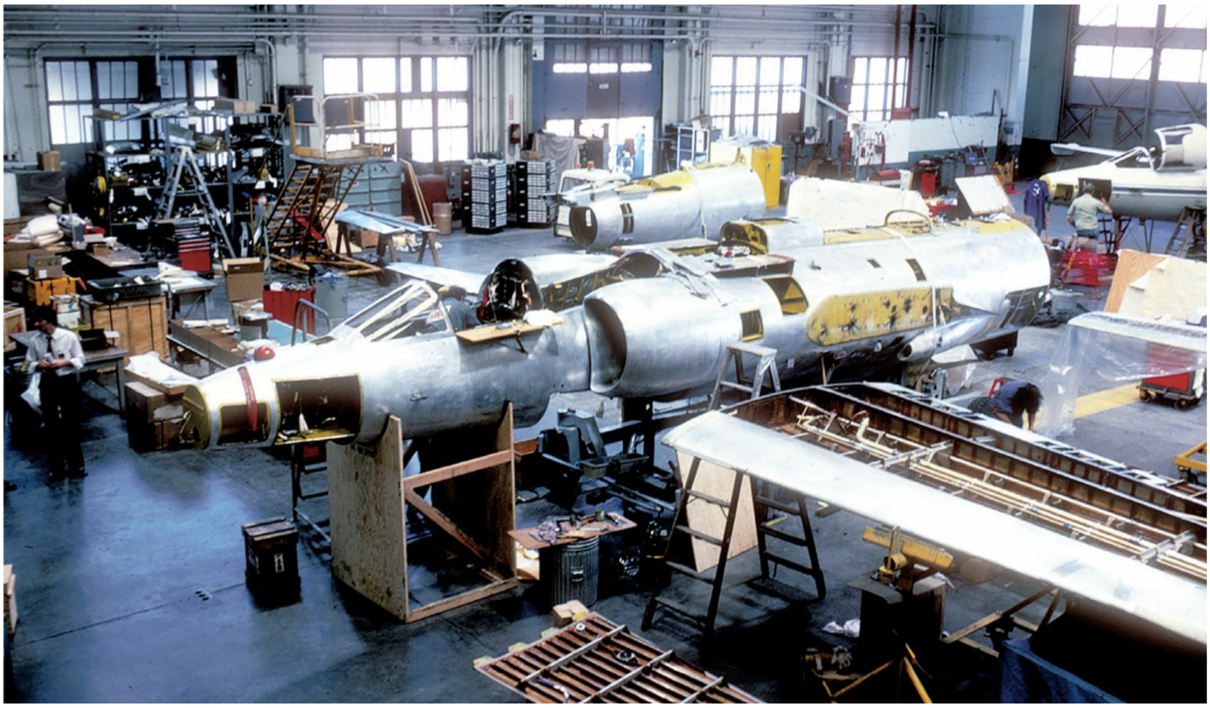
Probably the one of the most clearly unique U-2 configurations was the installation of the TRIM system on the top dorsal housing on this U-2F. The TRIM sensors were designed to measure the radiation characteristics of re-entry vehicles for future tracking criteria. The dedicated U-2 operated the TRIM program for two years before the program was terminated. (Author's collection)

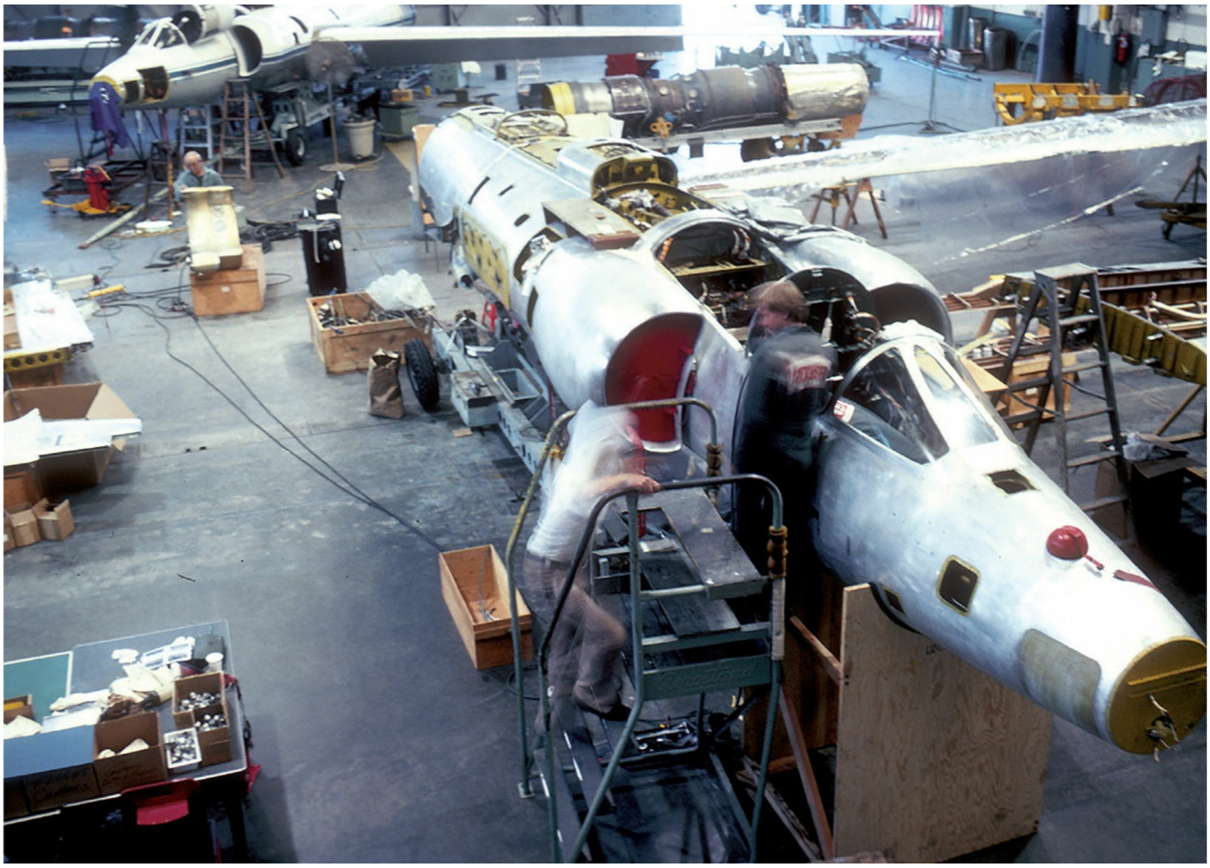


The launch crew rides the wing as U-2A 56-6722/389 taxis for takeoff. This U-2A was delivered to the Air Force in November 1957 and directly assigned to the Air Research Development Center (ARDC). It was never modified to "C" standards and was retired in 1978. (Author's collection)

NASA's very first ER-2A, an Earth resources aircraft used as flying laboratories in the Sub-Orbital Science Program, captured on the ramp at NASA Ames In May 1981. It was an error that caused the author to double expose this shot; it turned out so unique, he had to use it. (James C. Goodall)







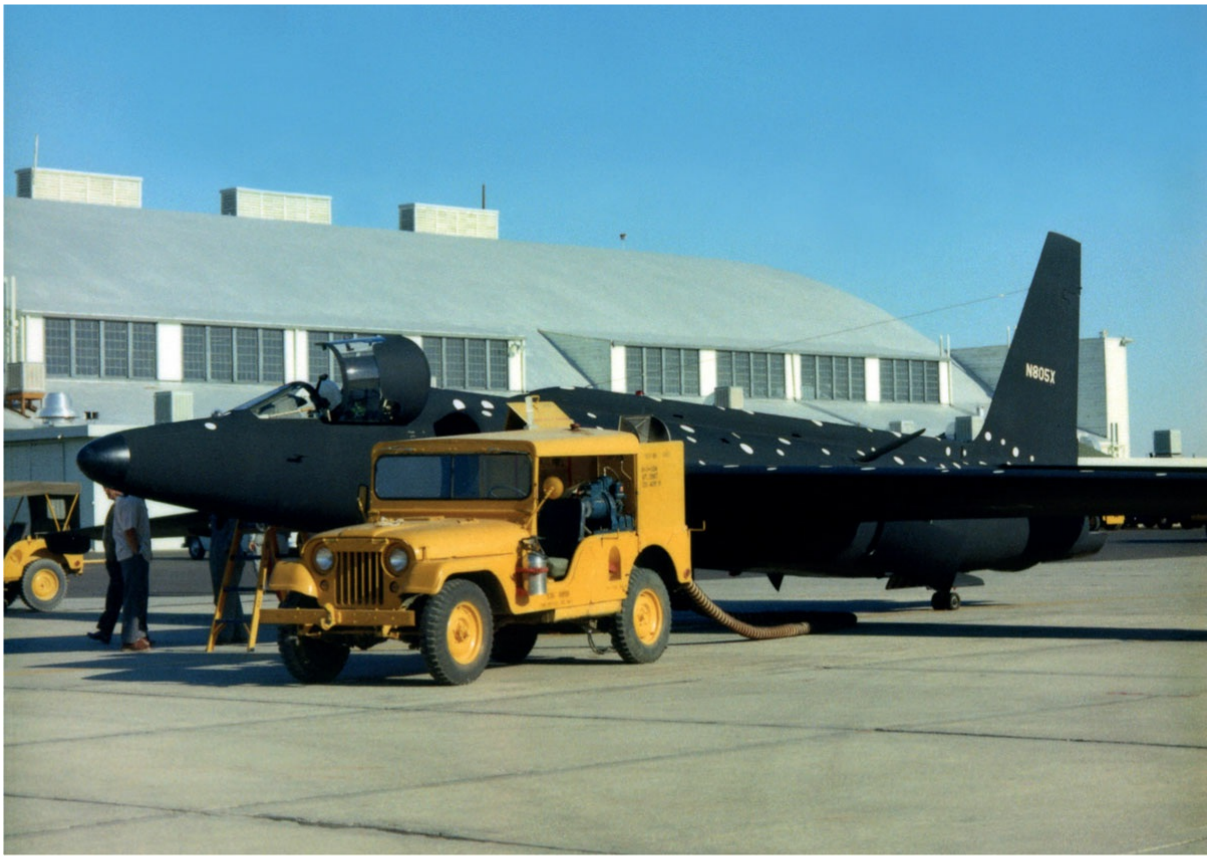
The two NASA U-2CS undergoing a major overhaul or "D" check at NASA Ames Fight Research Center located at the then Moffett Naval Air Station, Mountain View, CA. The photos were taken in the early 1980s. (James C. Goodall)

This U-2A, 56-6722/389, modified to the HICAT (High-altitude Clear Air Turbulence) configuration, is photographed flying in parallel with the main taxiway at Edwards AFB. Just below the U-2 is the North American XB-70 Valkyrie on its engine runup pad. (Author's collection)

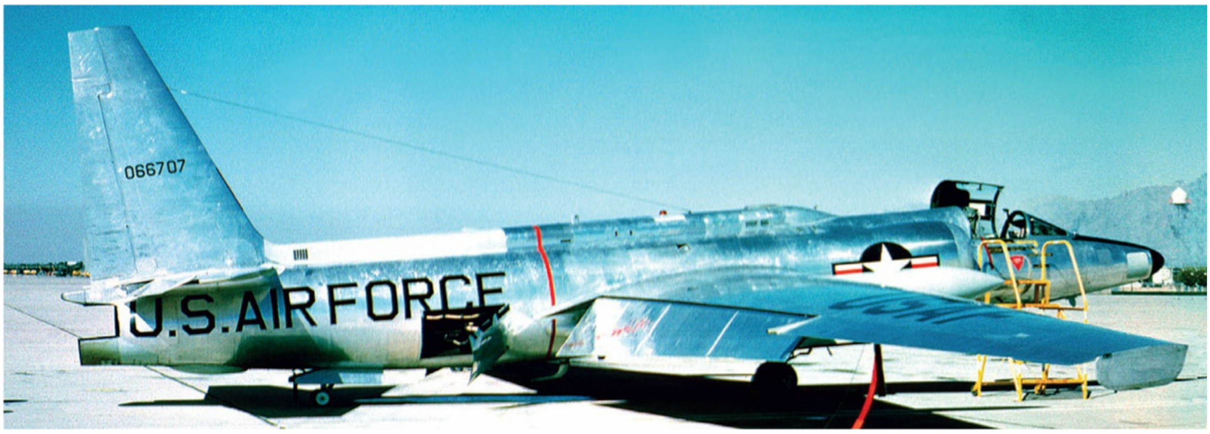
ARMSTRONG
FLIGHT RESEARCH CENTER
806
NASA

806
NASA
EXIT

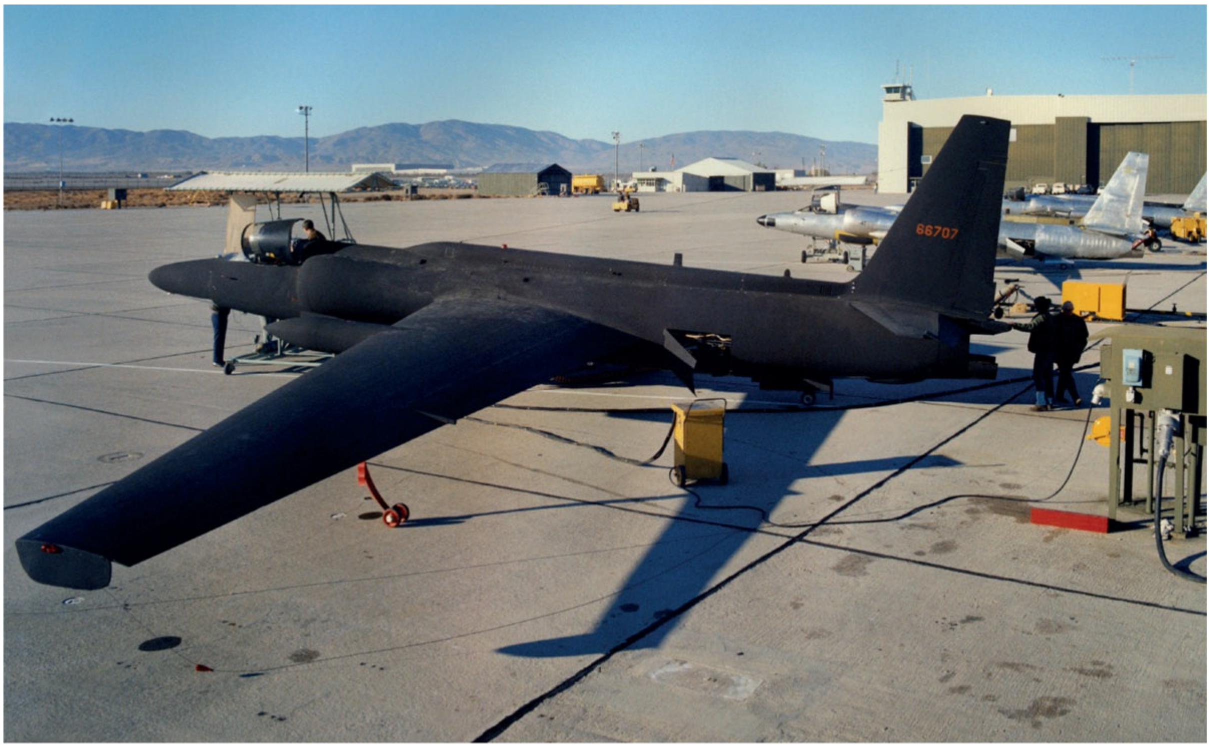
A photo shoot on 27 February 2015 at the ER-2's new location at Air Force Plant 42, Site 5. The NASA ER-2s are undergoing routine maintenance. Site 5 is also home to the NASA 747SP SOFIA airborne observatory. (James C. Goodall)



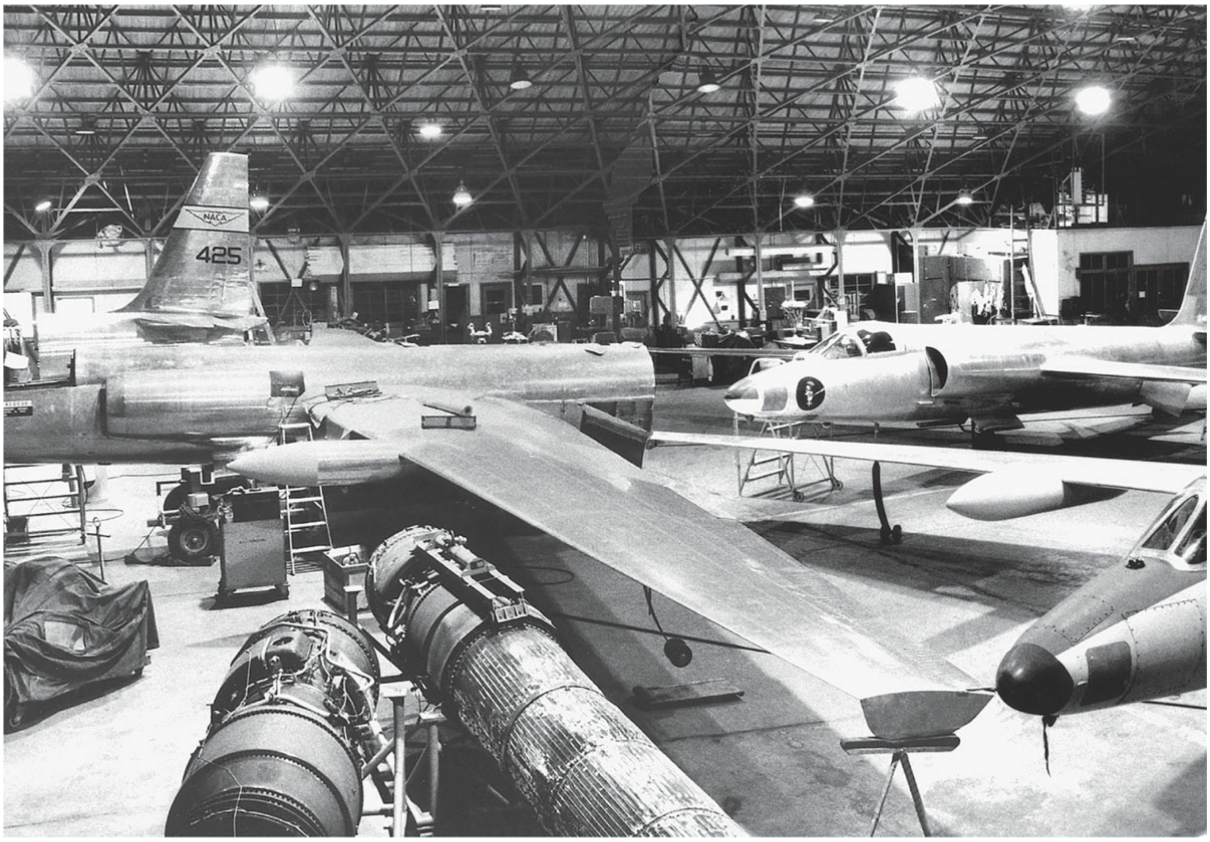
The "polka-dot" pattern on this CIA U-2B, N805X/56-6685, was used to test reconnaissance satellite sensors, but it had little if anything to do with protecting the U-2 in its high-altitude environment. (Lockheed Martin)



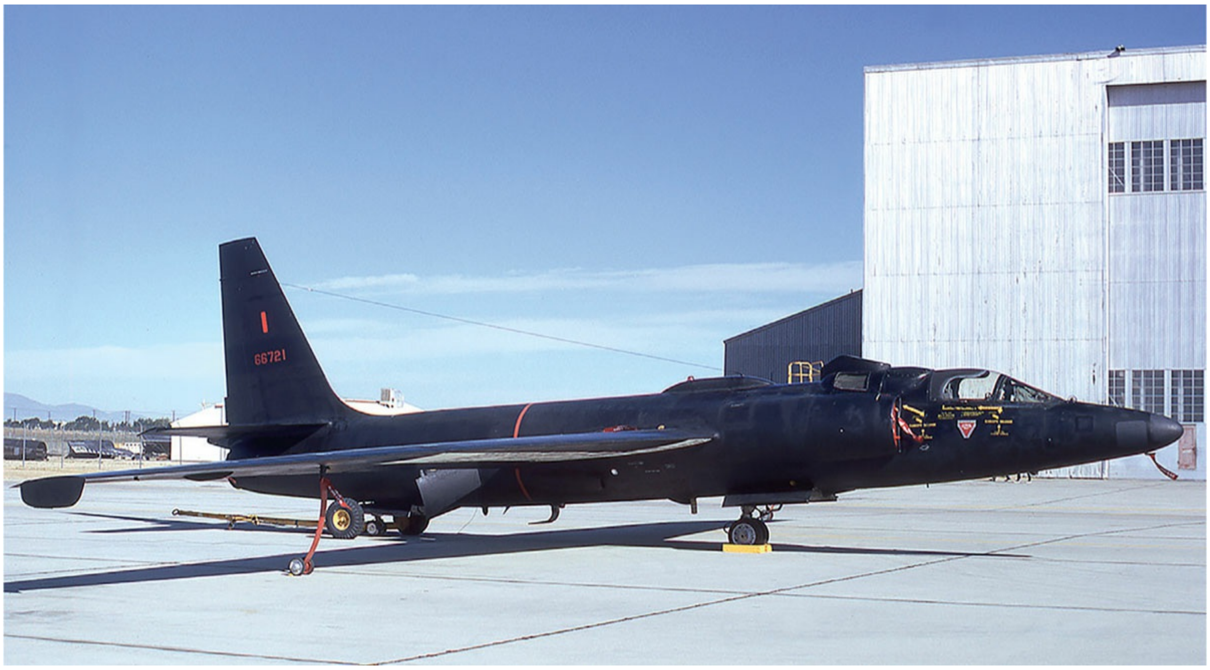
A clean shot of U-2C 56-6707/374 taken at Edwards AFB, in natural metal. Article 374 was delivered to the Air Force in May 1957. It was modified as a ferret aircraft in 1959; converted to a U-2E in 1962; converted to U-2F standards in November 1966; converted back to U-2C and configured to Airborne Location Strike System (ALSS) project in the early 1980s. (Author's collection)



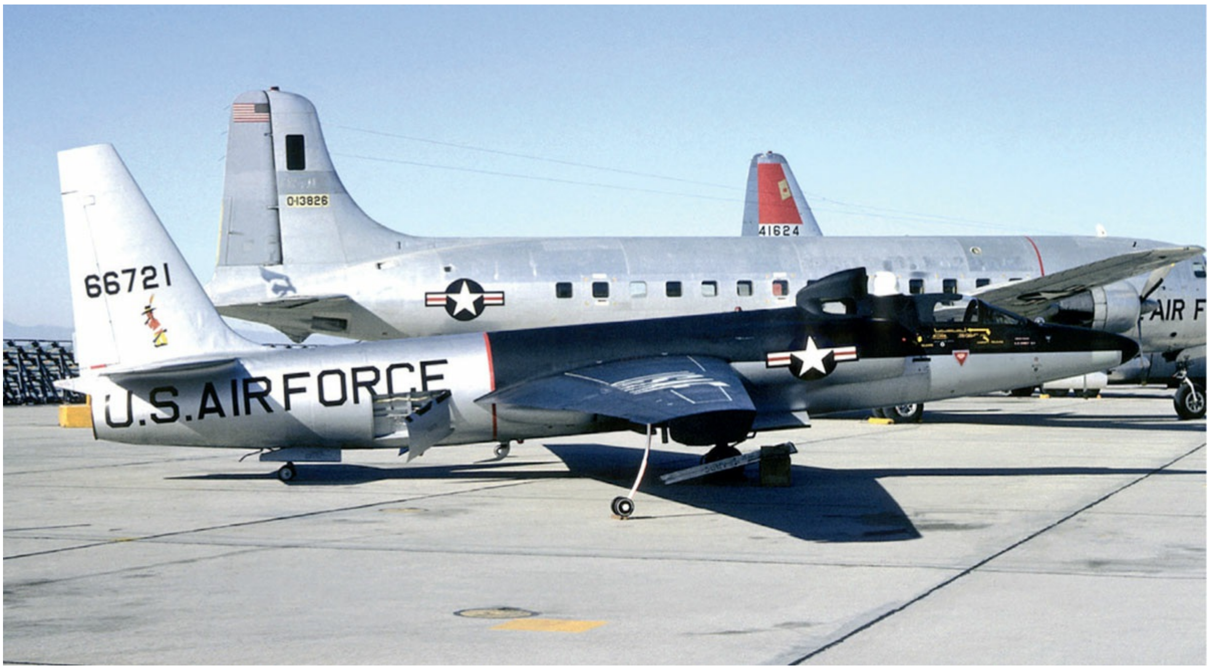
A lineup of U-2Cs at Air Force Plant 42, Site II, the Lockheed SR-71 and U-2 flight-test and depot facility. From front to back: U-2C 56-6707/374; U-2C 56-6680/347 and, the farthest away, U-2C 56-6700/367. (Lockheed Martin)



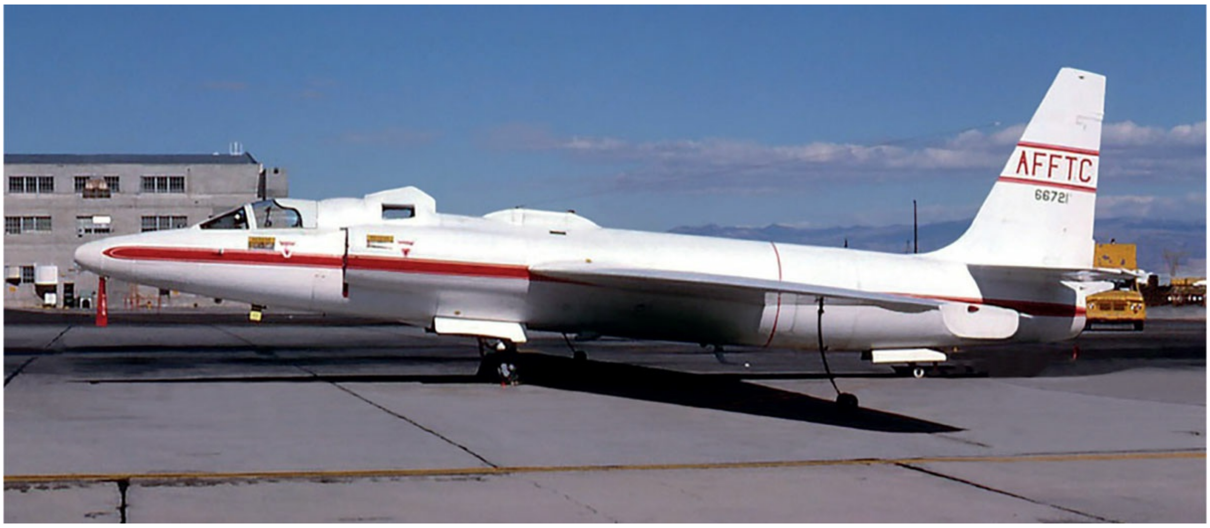
Pictured in their hangar, the CIA's U-2As are secured from prying eyes while assigned to Detachment A at Atsugi, Japan, during 1957. The closest U-2A represents what is most likely the world's very first "low-observable" treatment used on a U-2. The material that covers the bottom of the U-2A is a ferrite impregnated material that absorbs the radiated energy for hostile radar. (Author's collection)



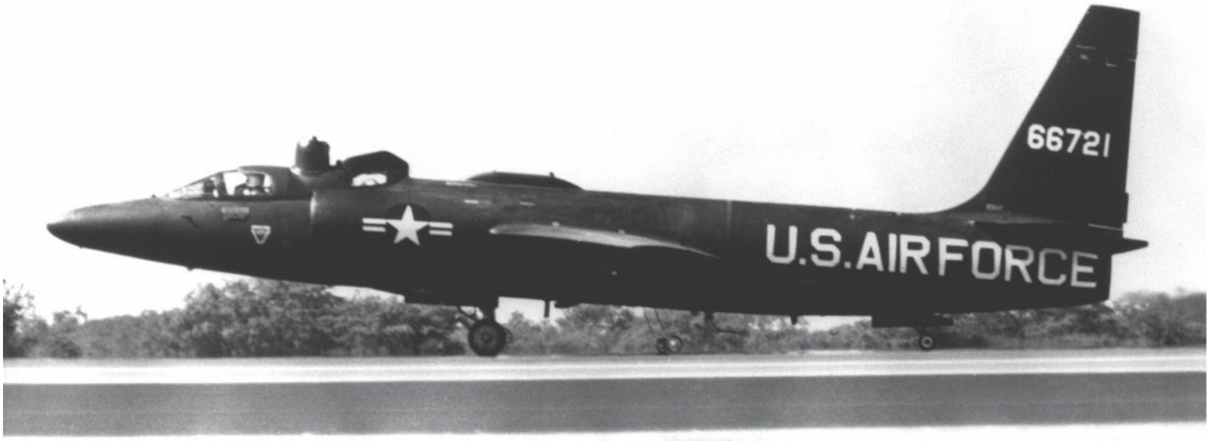
U-2D 56-6721/388 on the flight line at Edwards AFB. At the time it was assigned to the 6512th Test Group. (Author's collection)


66721
U.S.AIRFORCE
013826
41624
AIR F

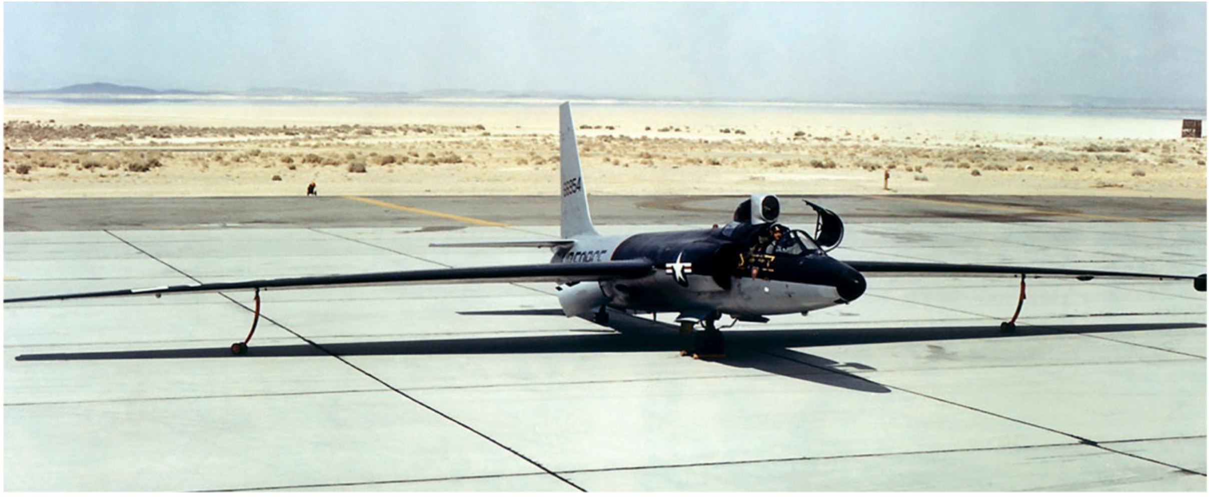
U-2D 56-6721/388 on the flight line at Edwards AFB as it was readied for the base's annual air show in 1965. (EAFB/HO)


AFFTC
66721

U-2D 56-6721/388, photographed in what was apparently its last major paint scheme. (Author's collection)

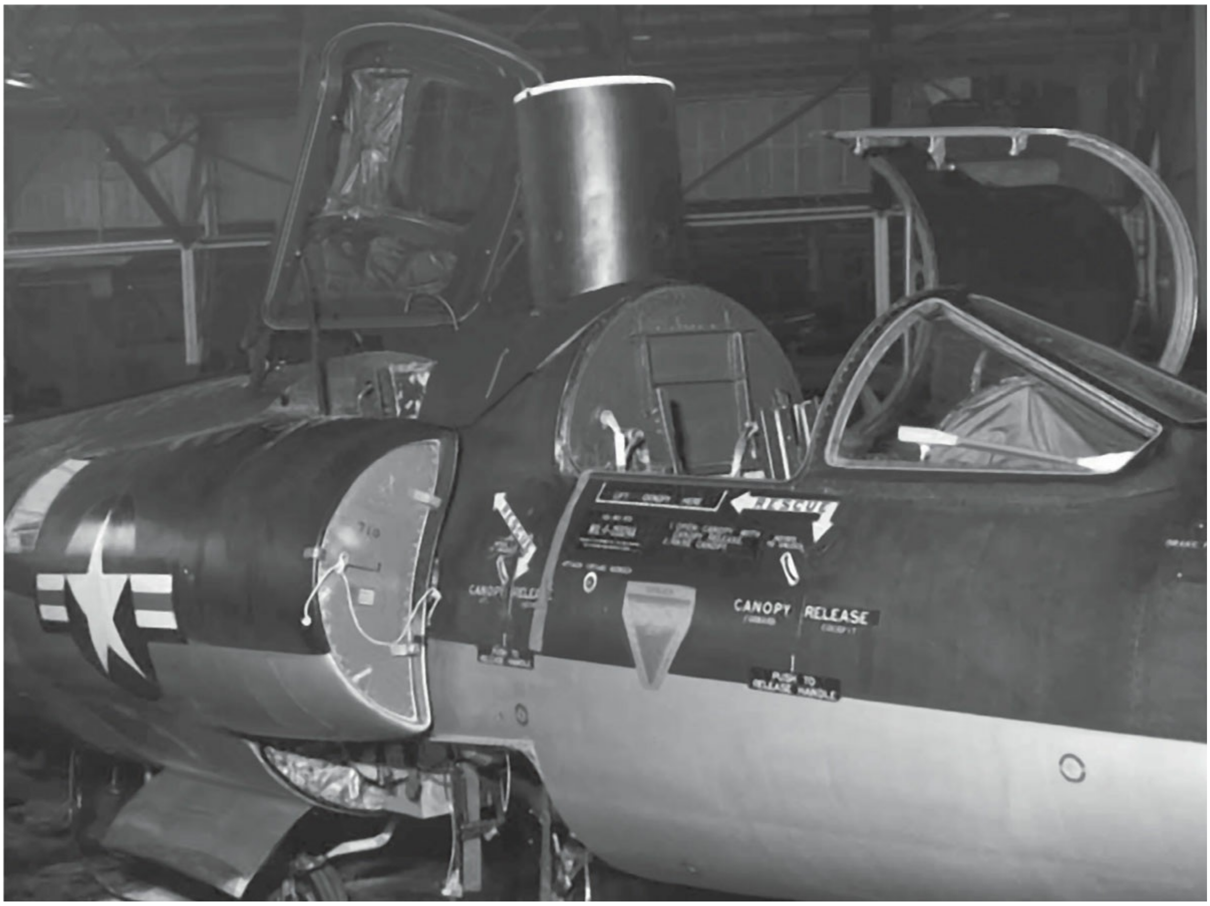

66721
U.S. AIR FORCE

U-2D, 56-6721/388, shot at Hickam AFB, HI, in July 1971. (USAF)

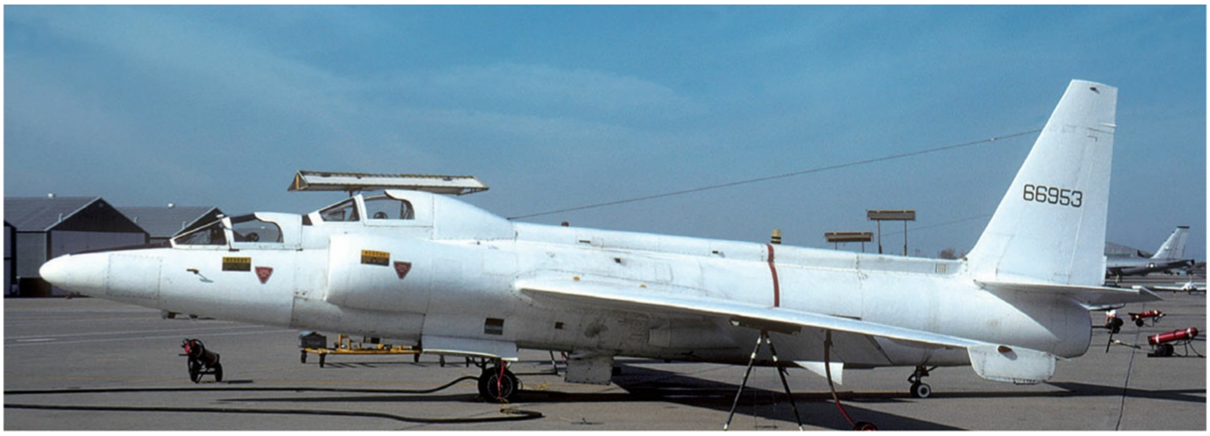


This is the second U-2D, 56-6954/394, delivered to the Air Force in March 1959. It was purpose built and assigned to ARDC at Edwards AFB. It was transferred to Strategic Air Command (SAC) in 1966 and converted to a standard "C" model in 1967. It was written off in a crash near Tucson on 31 May 1968. (USAF)

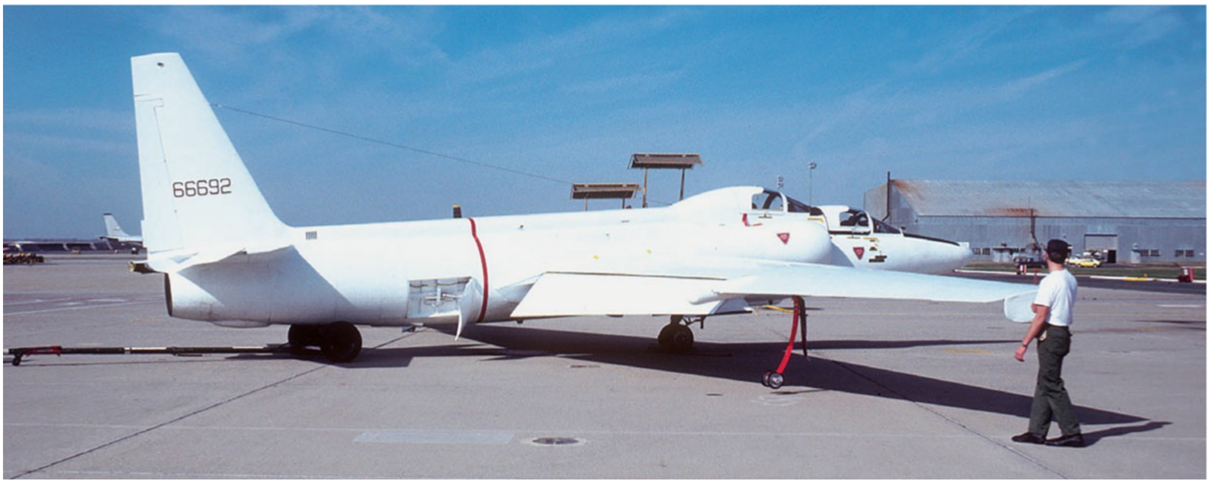
RESCUE
LIFT CANOPY HERE
1 OPEN CANOPY WITH CANOPY RELEASE
2 RAISE CANOPY
RESCUE
CANOPY RELEASE
PUSH TO RELEASE HANDLE
DANGER
UPWARD EJECTION SEAT
CANOPY RELEASE
PUSH TO RELEASE HANDLE



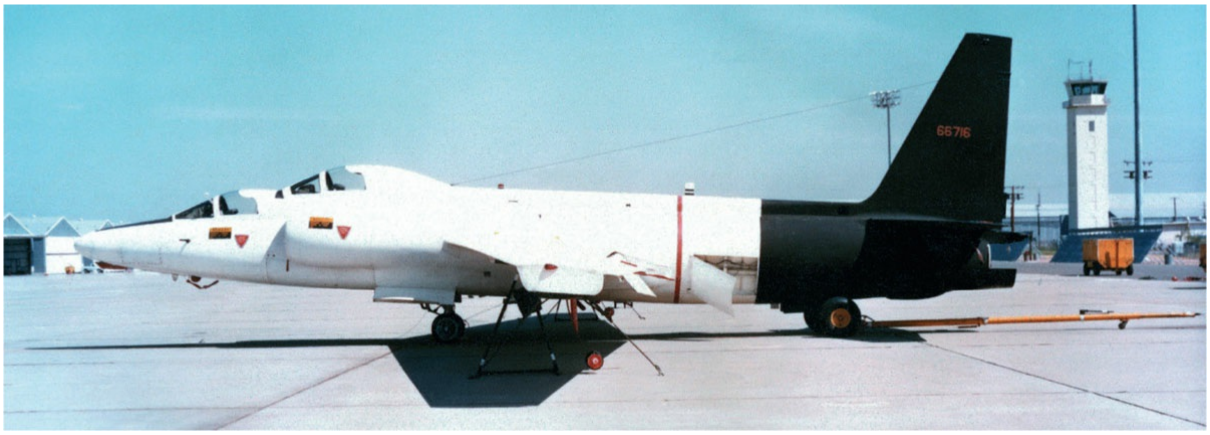
Both U-2As that were converted to the two-place "D" configuration were modified to accommodate a second crewman, as well as a suite of equipment to measure infrared emissions from aircraft and missiles, in an effort to provide an early warning of a Soviet nuclear attack. (Author's collection)



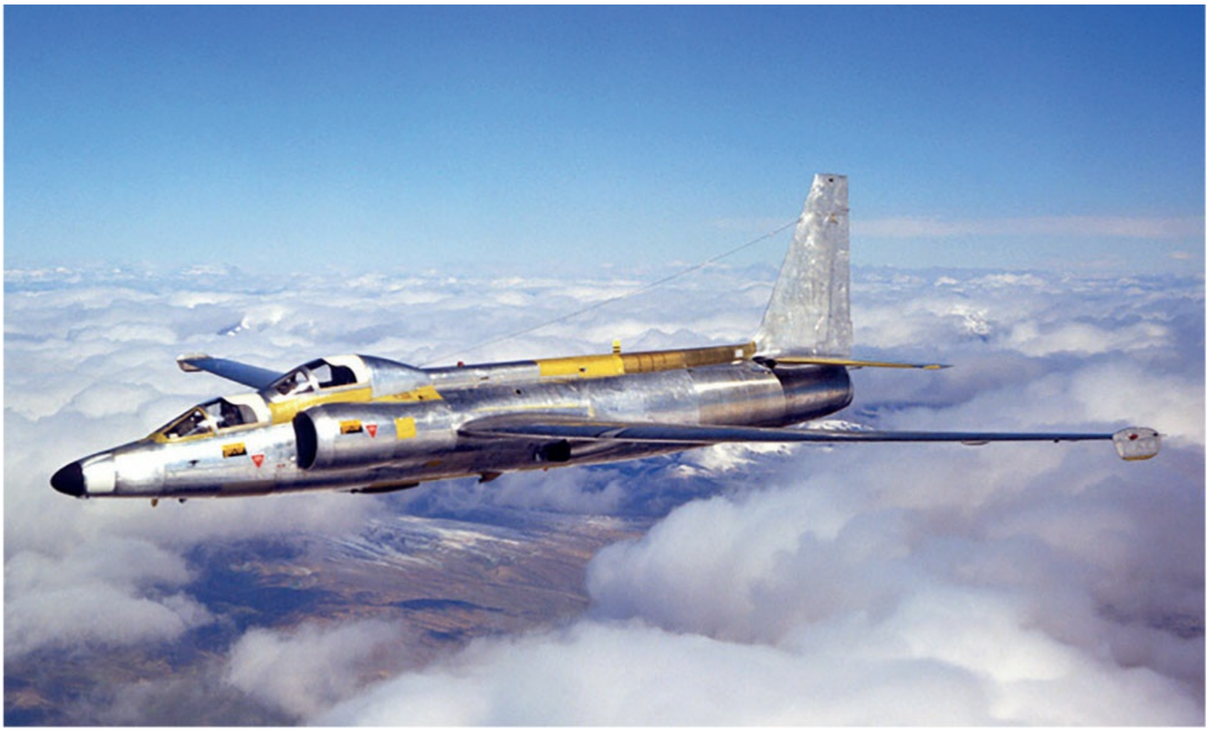
The second U-2CT, 56-6953/393, was originally delivered to the Air Force in February 1959 as an "A" model. It was damaged in a landing accident at Davis Monthan AFB in May 1971. (James C. Goodall)



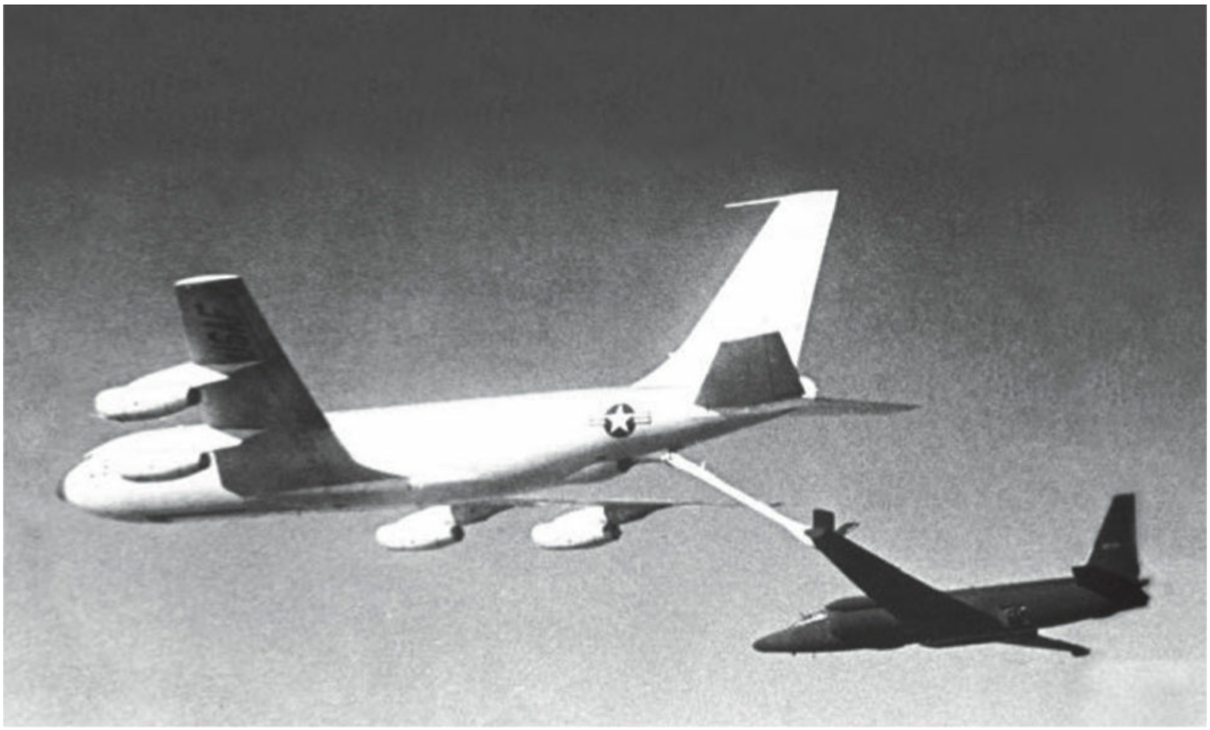
The original U-2CT 56-6692/359, photographed on the ramp at Beale AFB in the mid-1980s. It was delivered to the CIA on 22 October 1956 and later transferred to Strategic Air Command in December 1960. (Author's collection)



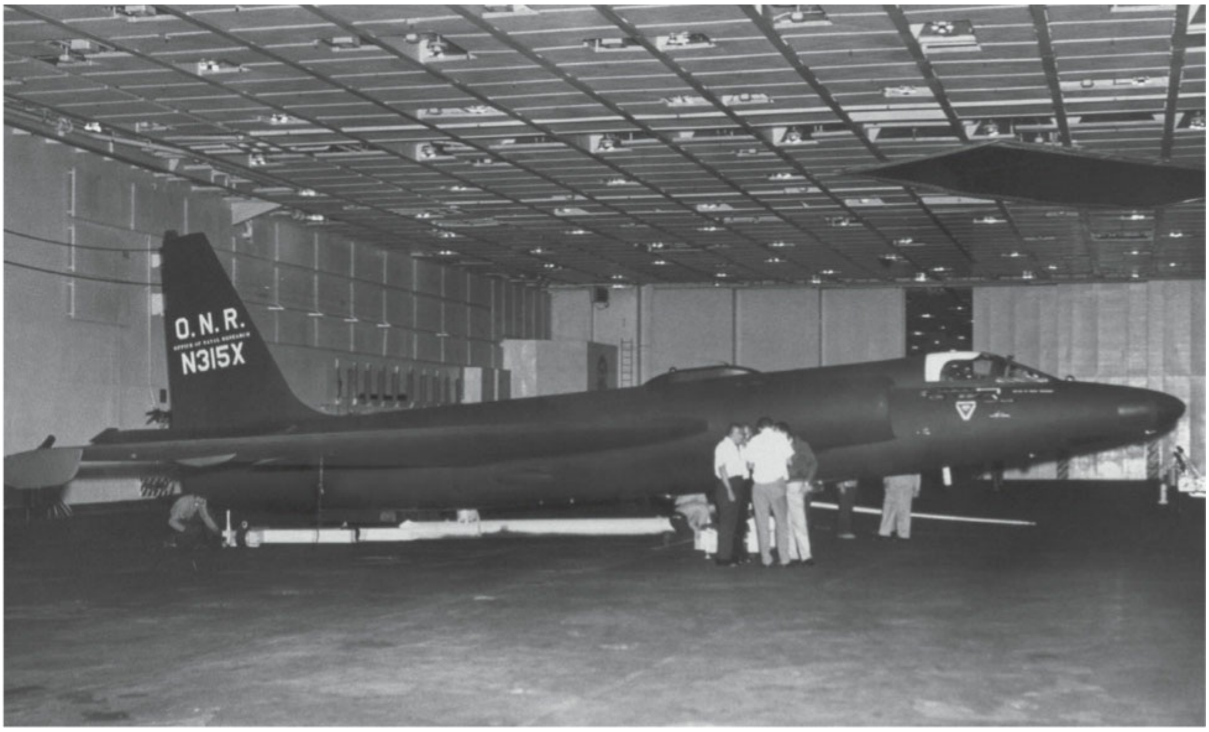
U-2CT 56-6692/359, photographed on the ramp at Beale AFB in the mid-1980s. It is using the after fuselage of U-2C 56-6716. (Author's collection)



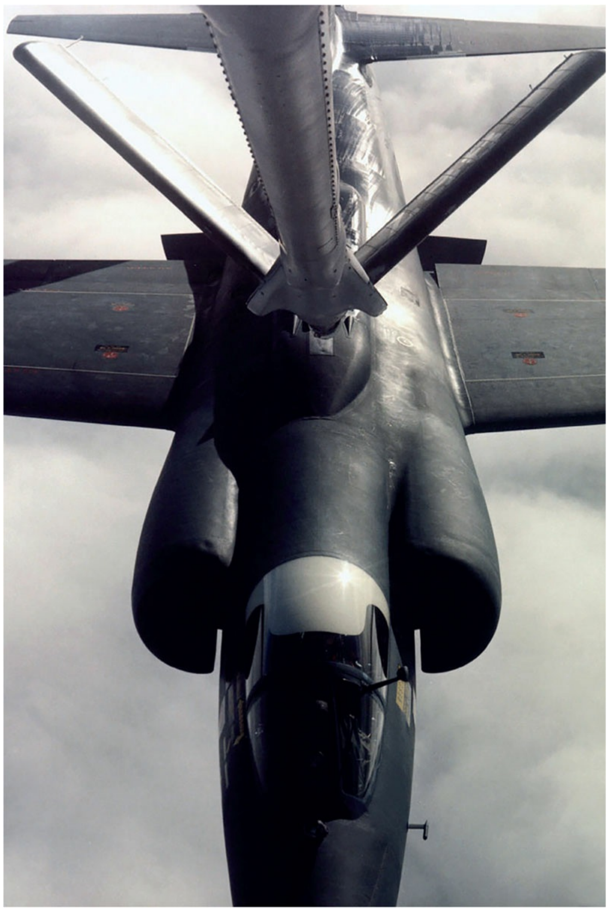
The first flight of the unpainted U-2CT, 56-6692/359, in January 1976. (Lockheed Martin)



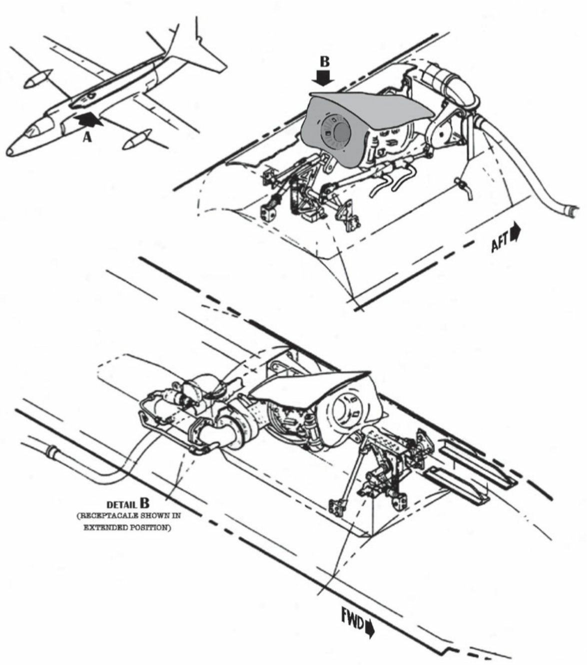
In 1962, three Strategic Air Command (SAC) pilots were selected and sent to Edwards AFB and assigned to the CIA U-2 operation at North Base. Once there, the SAC pilots would learn how to fly and be refueled in the U-2F model. (Author's collection)


O.N.R.
OFFICE OF NAVAL RESEARCH
N315X

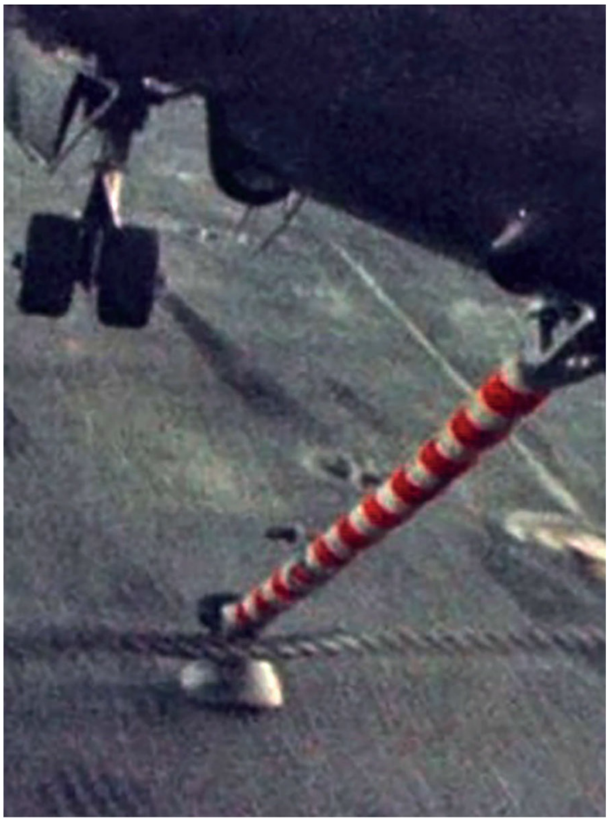
The Navy Office of Naval Research program "Project Seeker" resulted in a U-2A, with civil registration N315X, being modified into "F" configuration and being qualified to land on a carrier during testing in 1963. (Lockheed Martin)



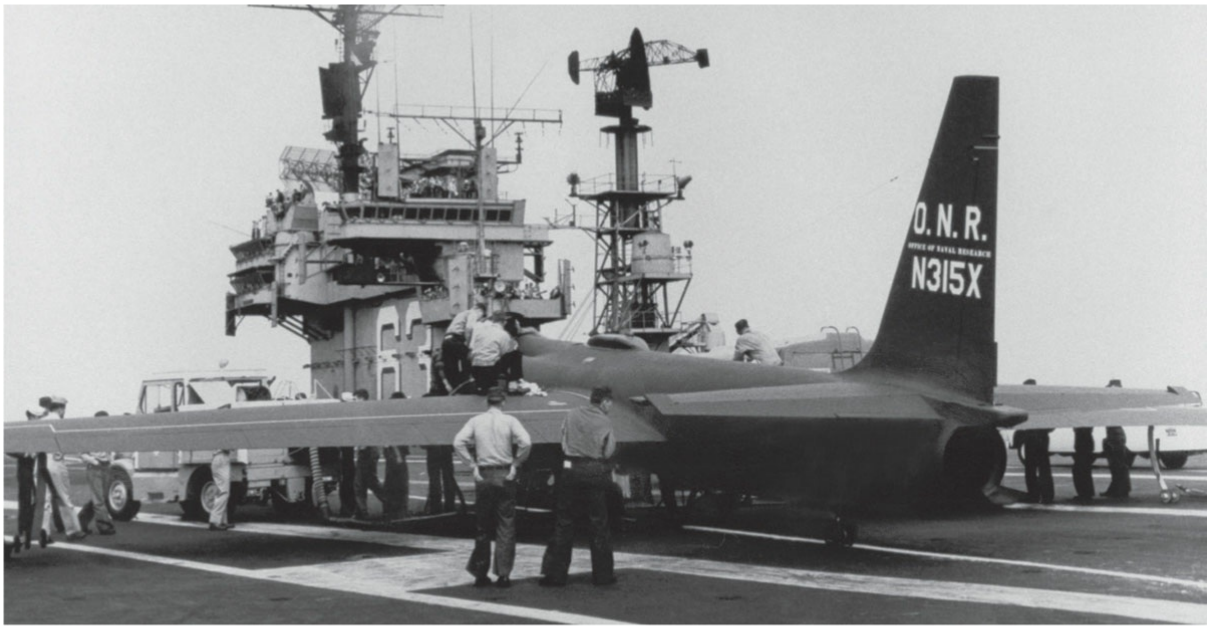
A U-2F takes on fuel from a Boeing KC-97L. When refueling the U-2Fs or the single U-2H the receiving U-2 was usually flown with the flaps in the gust relief position and used the speed brakes to precisely control its airspeed. (Author's collection)


B
A
AFT
DETAIL B
(RECEPTACALE SHOWN IN EXTENDED POSITION)
FWD

Technical order drawing of the refueling modification used on the U-2F and U-2H. Redrawn by the author. (James C. Goodall)



Closeup of the arresting hook used on the U2Fs and U2Gs. (Author's collection)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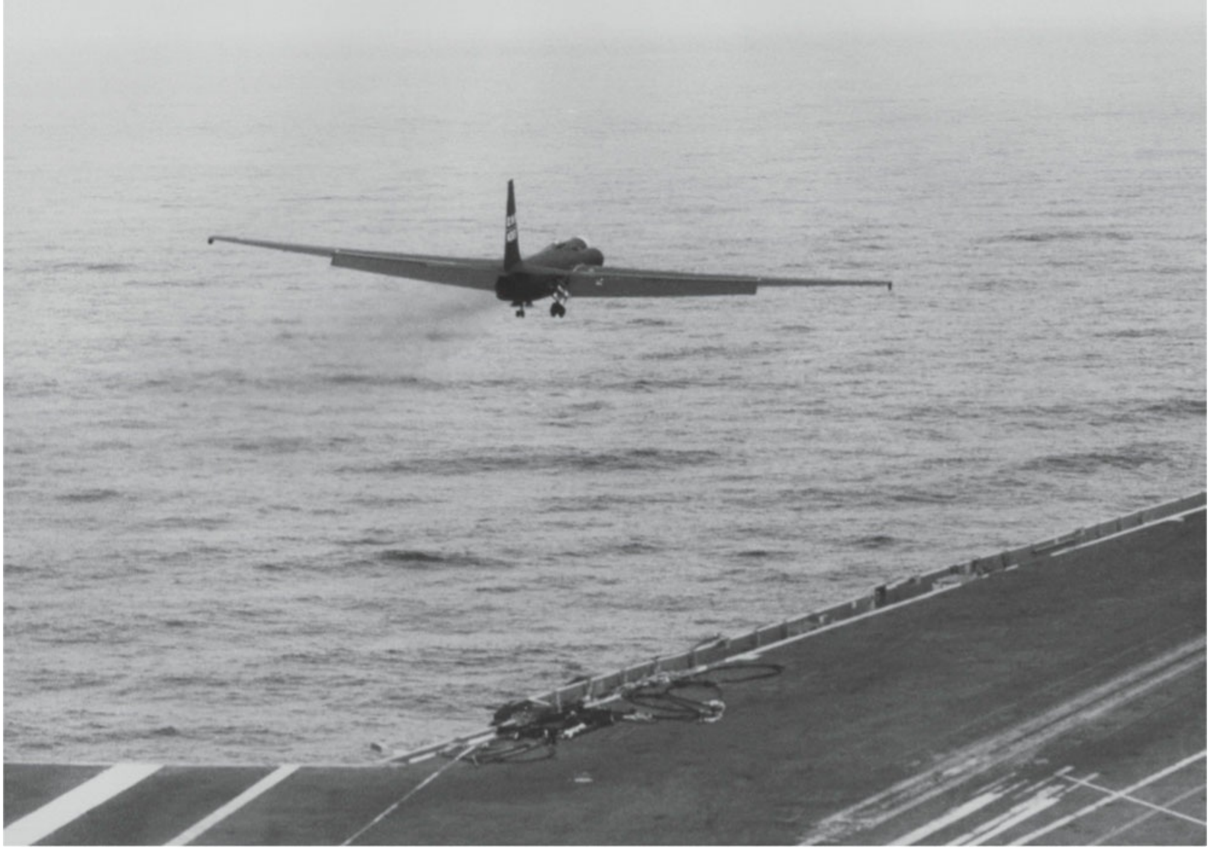
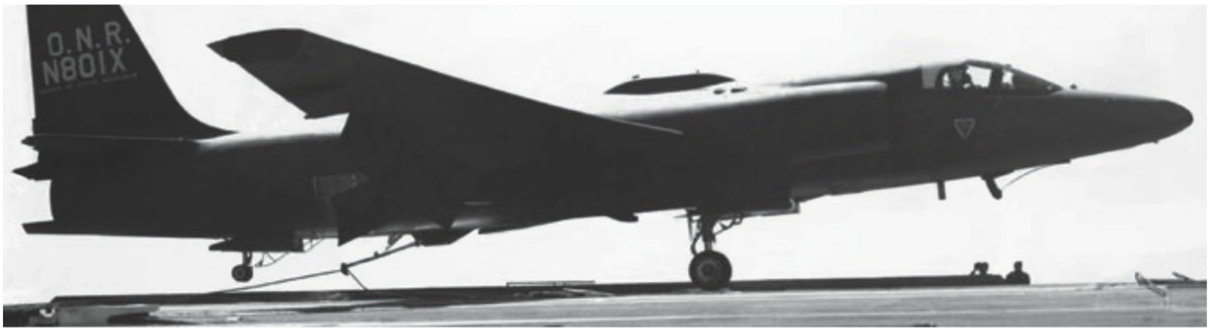
OFFICE OF NAVAL RESEARCH
N315X

U-2F N315X on the flight deck of the USS *Kitty Hawk* (CV 63) during landing trials in 1963. (Lockheed Martin)

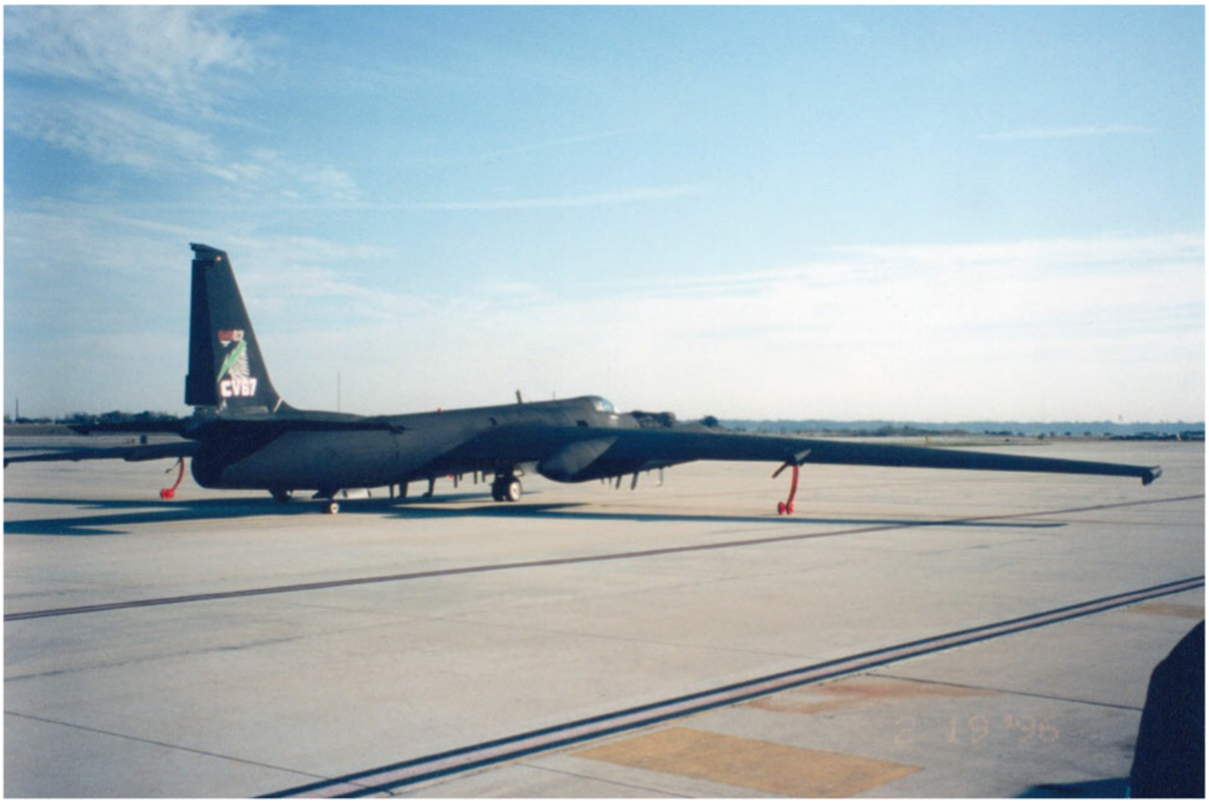


U-2F N810X flown in response to a need outlined by the Office of Naval Research, does a fly-by to look over the landing site before committing to land on the USS

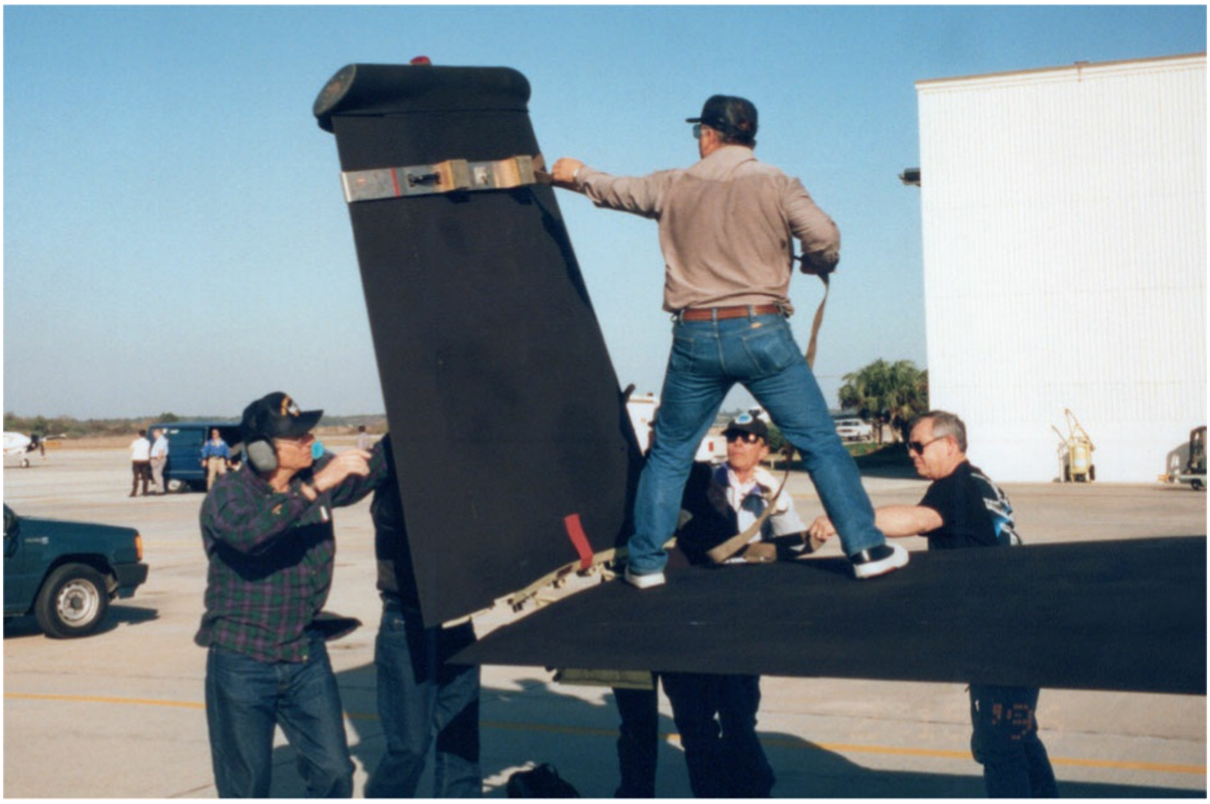
Kitty Hawk (CV 63) during landing trials in 1963. (Lockheed Martin)



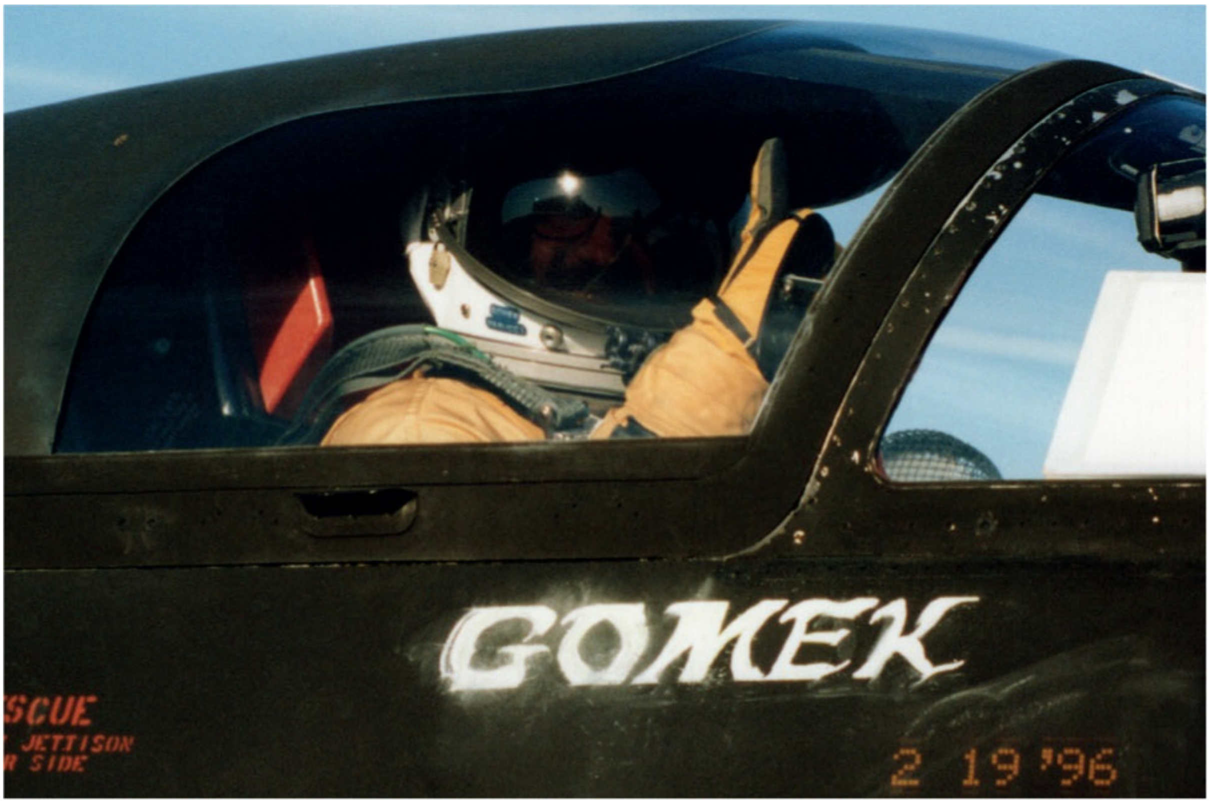
A modified "pogo" wheel was mounted just under the cockpit in order to protect the nose of the U-2 if it were to nose down on landing. (Lockheed Martin)



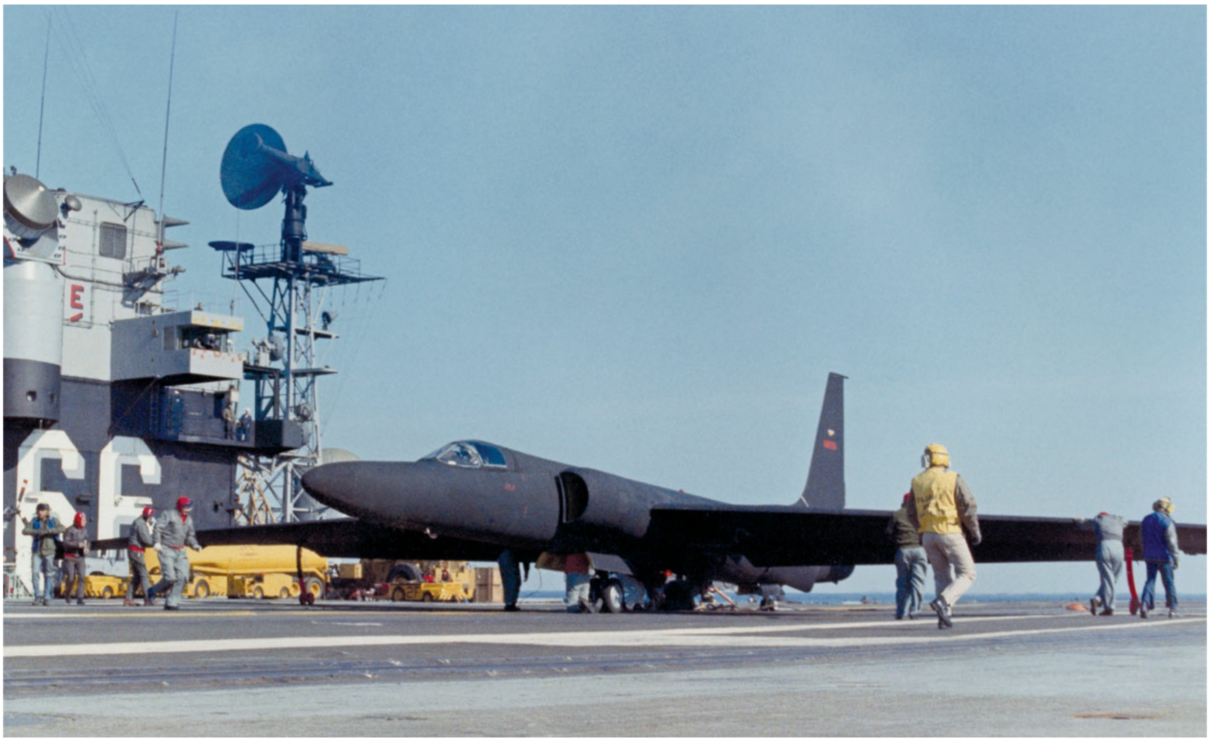
U-2R 80-1067/067 taxis down the runway at Key West, FL, in preparation for a carrier landing trial on the USS *John F. Kennedy* (CVA 67) on 19 February 1996. (Author's collection)



Retired Air Force colonel, former SR-71 pilot and then-head of Lockheed's U-2 flight-test at Site II, Tom Pugh heads up the folding of the U-2R's wing tips that allow the U-2R/S to land on a modern CVN-class aircraft carrier. (Author's collection)


GOMEK
SCUE
JETTISON
R SIDE
2 19 '96

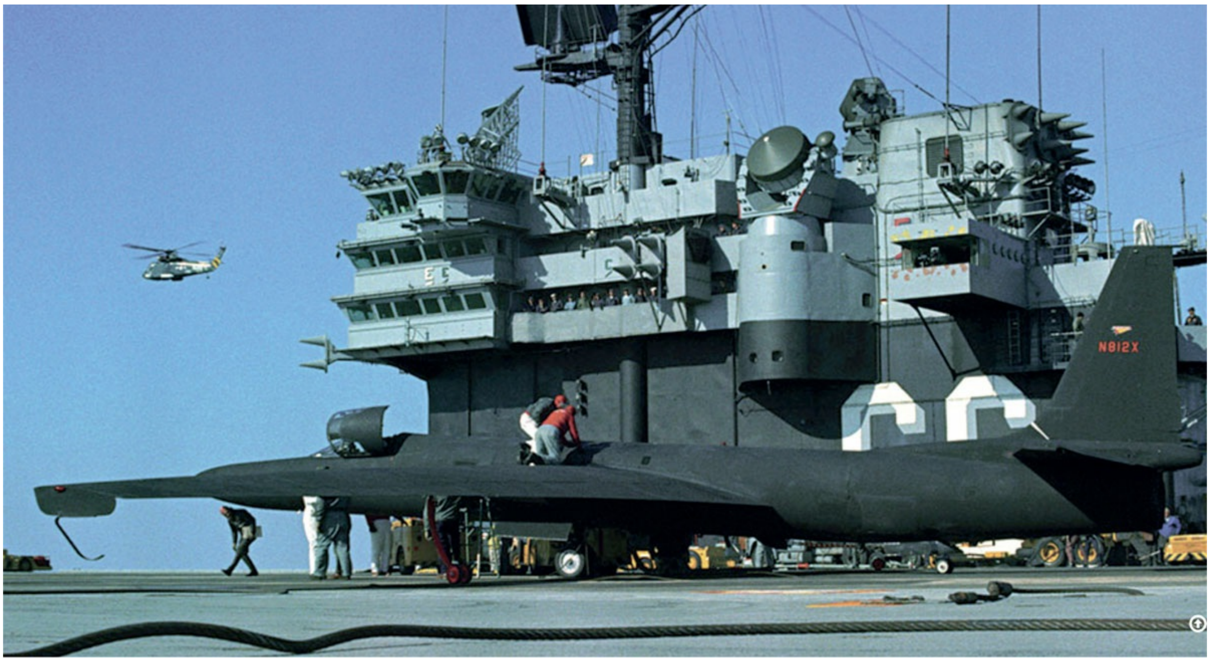
A closeup of the chalk-applied name on the U-2R prior to takeoff. (Author's collection)



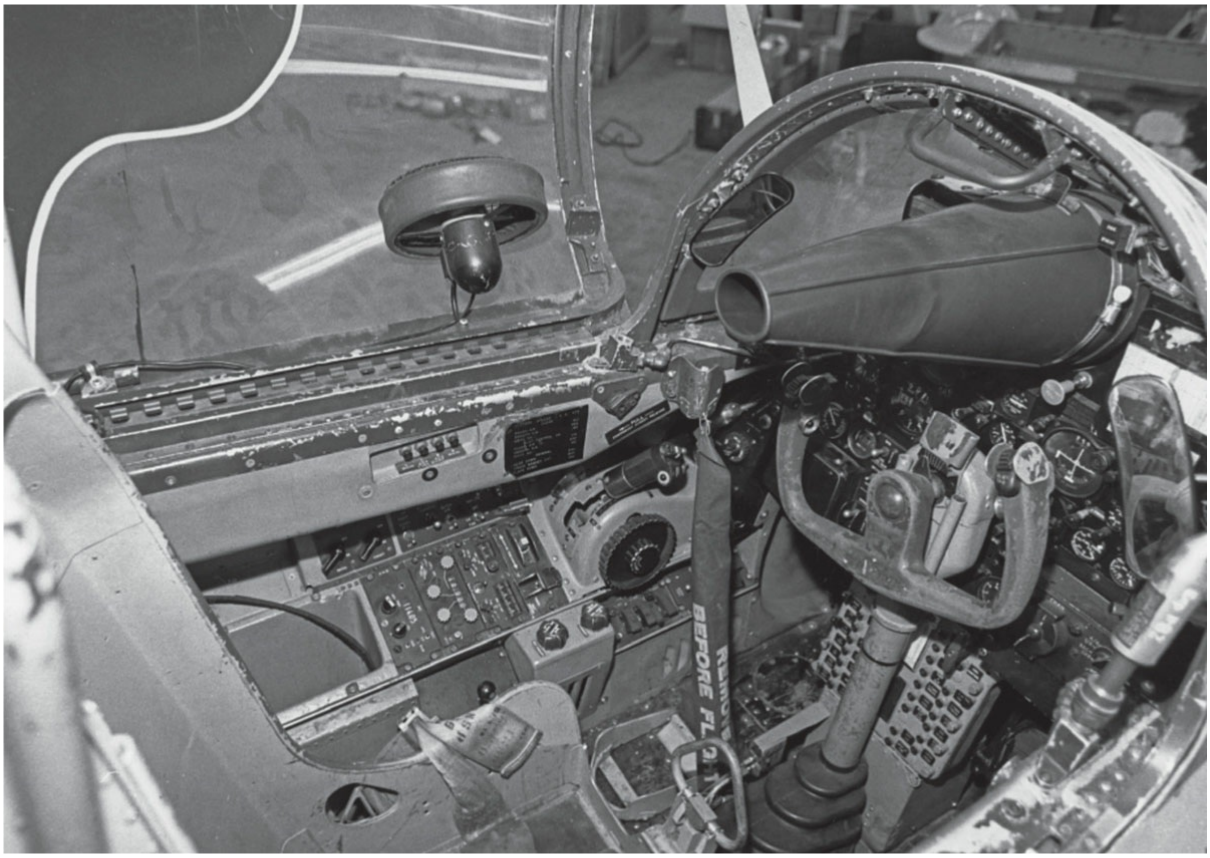
A U-2R, sporting civil registration N812X, has just landed on the USS *America* (CVA

66) during November 1969 landing trials. (Lockheed Martin)

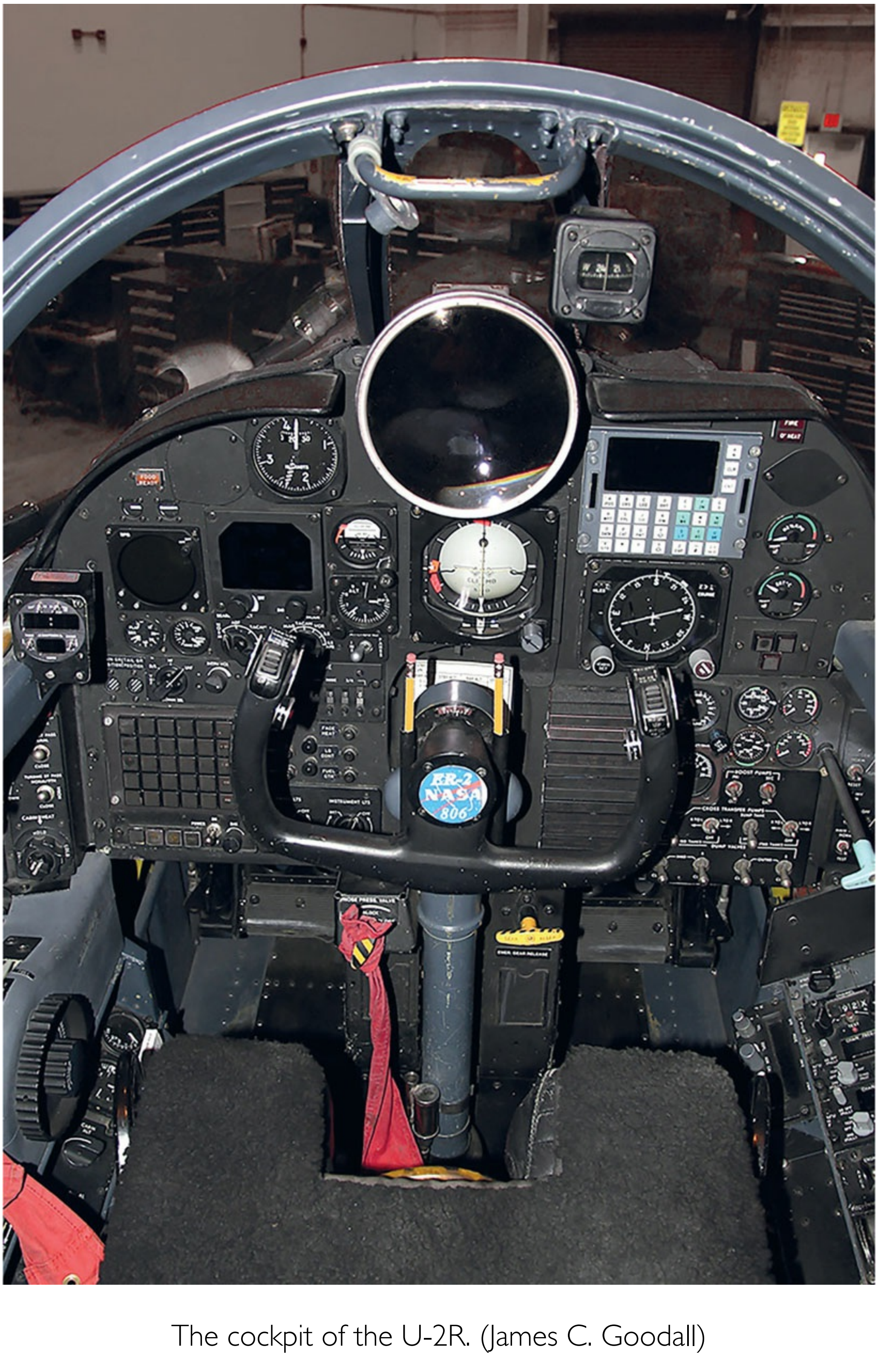
A U-2R on approach during a fly-by over the flight deck of the USS *America* (CVA 66) in the early winter of 1969. (Lockheed Martin)



A U-2R, with civilian registration N812X, is prepped for takeoff on the USS *America* (CVA 66) after several successful landings and takeoffs. (Lockheed Martin)


REMOVE BEFORE FLIGHT

The cockpit of the original U-2A. (USAF)



The cockpit of the U-2R. (James C. Goodall)

JETSTAR L-329

1957

PROGRAM: L-329/L-1329/C-140

Name: JetStar

Mission: Business jet – military transport

Length: 60ft 5in (18.41m)

Wing Span: 54ft 5in (16.59m)

Height: 20ft 5in (6.22m)

Max T.O. Weight: 44,500lb (20,185kg)

First Flight: 4 September 1957

Last Flight: Still active

Crew: 2

Number Built: 202 plus 2 prototypes

Power Plant: 4 x Pratt & Whitney JT12s; 4 x Garrett TFE731-1 turbofans; prototype: 2 x Bristol Siddeley Orpheus

Design Speed: Mach 0.66 (504mph; 811km/h)

Service Ceiling: 43,000ft (13,106m)

Combat Radius: N/A

Weapons Load: 8–10 passengers

The Lockheed JetStar (company designations L-329 and L-1329; designated C-140 in USAF service) is a business jet produced from the early 1960s to the 1970s. The JetStar was the first dedicated business jet to enter service. It was also one of the largest aircraft in the class for many years, seating ten plus two crew. It is distinguishable from other small jets by its four engines, mounted on the rear of the fuselage in a similar layout to the larger Vickers VC10 airliner that first flew several years later, and by the "slipper"-style fuel tanks fixed to the wings.

The JetStar originated as a private project within Lockheed, with an eye to winning a USAF requirement that was later dropped due to budget cuts. Lockheed decided to continue the project on their own for the business market. The first two prototypes were equipped with two Bristol Siddeley Orpheus engines, the first of these flying on 4 September 1957. The second was also equipped with the wing-mounted "slipper tanks", which were originally to be an option. Lockheed attempted to arrange a contract to produce the Orpheus in the United States, but when these negotiations failed, they re-engined the second prototype, N329K, with four Pratt & Whitney JT12s in 1959. The slipper tanks were removed and placed on the first prototype, N329J. N329J served as Clarence Johnson's personal transport for some time. The JT12 fit proved successful and was selected for the production versions, the first of which flew in mid-1960. These versions entered commercial service in 1961.

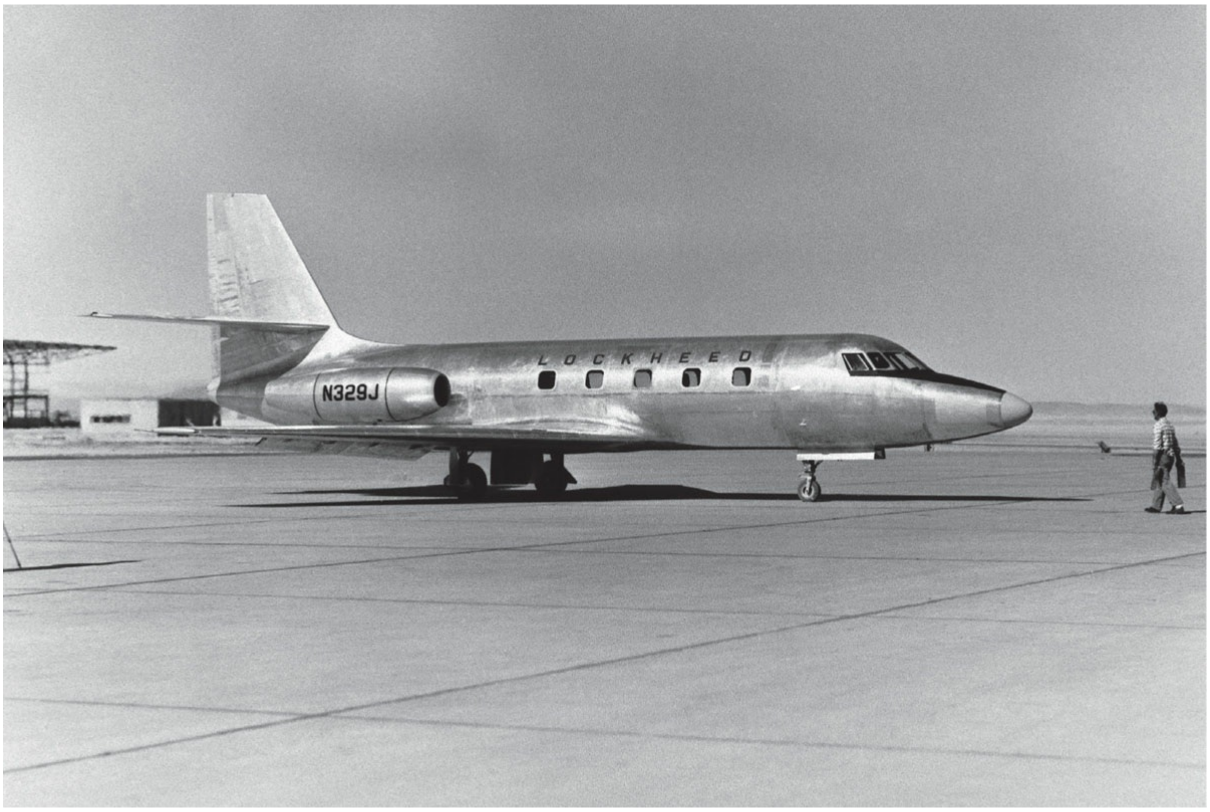
Sixteen JetStars were produced for the USAF. Five of these were C-140A flight inspection aircraft, designated to perform airborne testing of airport navigational aids from 1962. They began service during the Vietnam War and remained in service until the early 1990s. The "Flight Check" C-140A was a combat-coded aircraft that could be distinguished from the VIP transport version by its distinctive camouflage paint scheme. The last C-140A to be retired was placed on static display at Scott AFB, Illinois.

An additional 11 airframes were designated C-140B, although the first of these predated the C-140As when it was delivered in 1961. The C-140Bs were used by the Military Airlift Command to transport personnel, being operated as VIP transports by the 89th Military Airlift Wing at Andrews AFB, Maryland. These VIP aircraft were designated as VC-140Bs. The VIP transport fleet occasionally served as Air Force One during the 1970s and 1980s. Several other countries, such as Germany and Canada, have used military JetStars as transports for their heads of state, heads of government and other VIPs.

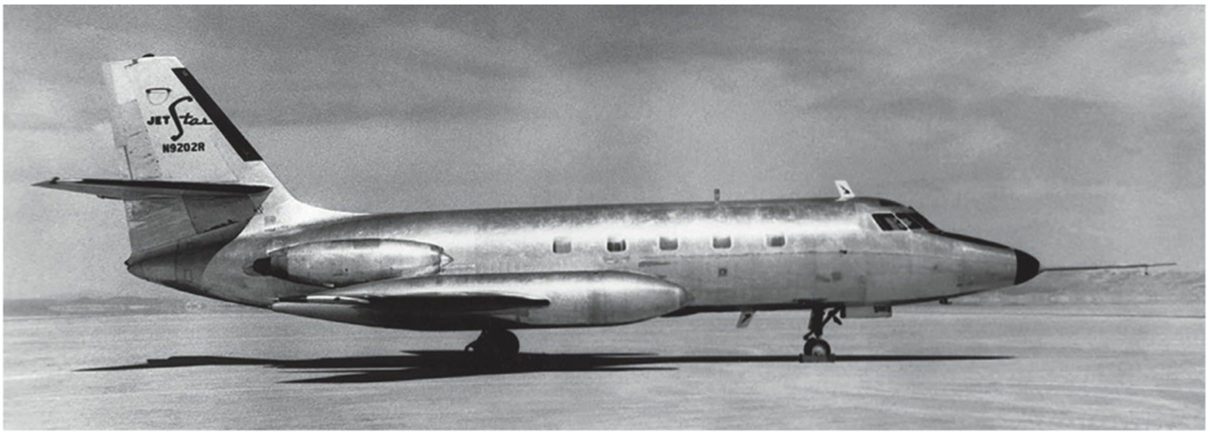
Noise regulations in the United States and high fuel consumption led to the development of the 731 JetStar, a modification program, which added new Garrett iResearch TFE731 turbofan engines and redesigned external fuel tanks to original JetStars. The 731 JetStar modification program was so successful that Lockheed produced 40 new JetStars, designated the JetStar II, from 1976 through 1979. The JetStar IIs were factory-new aircraft with the turbofan engines and revised external fuel tanks. Both 731 JetStars and JetStar IIs have greatly increased range, reduced noise and better runway performance than the original JetStars. JetStar production totaled 204 aircraft by final delivery in 1978. Most original JetStars have been retired, but many 731 JetStars and JetStar IIs are still flying in various roles, mainly as corporate and private jets.

LOCKHEED AIRCRAFT CORPORATION

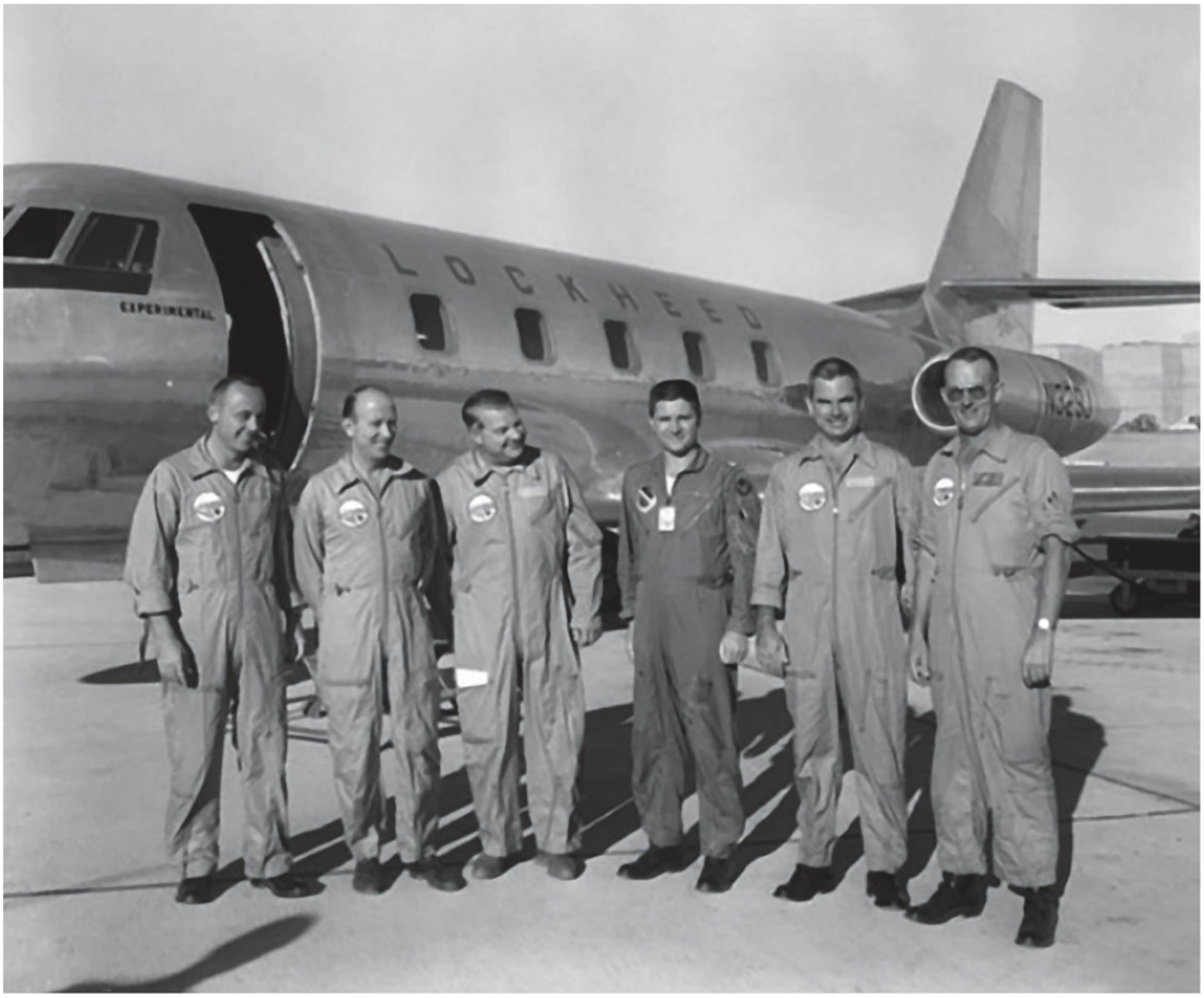
The prototype JetStar is shown taking off from the Hollywood Burbank Airport in one of its many different paint schemes. (Lockheed Martin)



Early shots of the prototype JetStar only carried the FAA registration of N329J and "Lockheed" above the windows. (Lockheed Martin)



The first JetStar, N329J, almost certainly at the end of its very first test flight on 4 September 1957 with Skunk Works test pilot Ray Goudey and co-pilot Robert Schumacher. (Lockheed Martin)



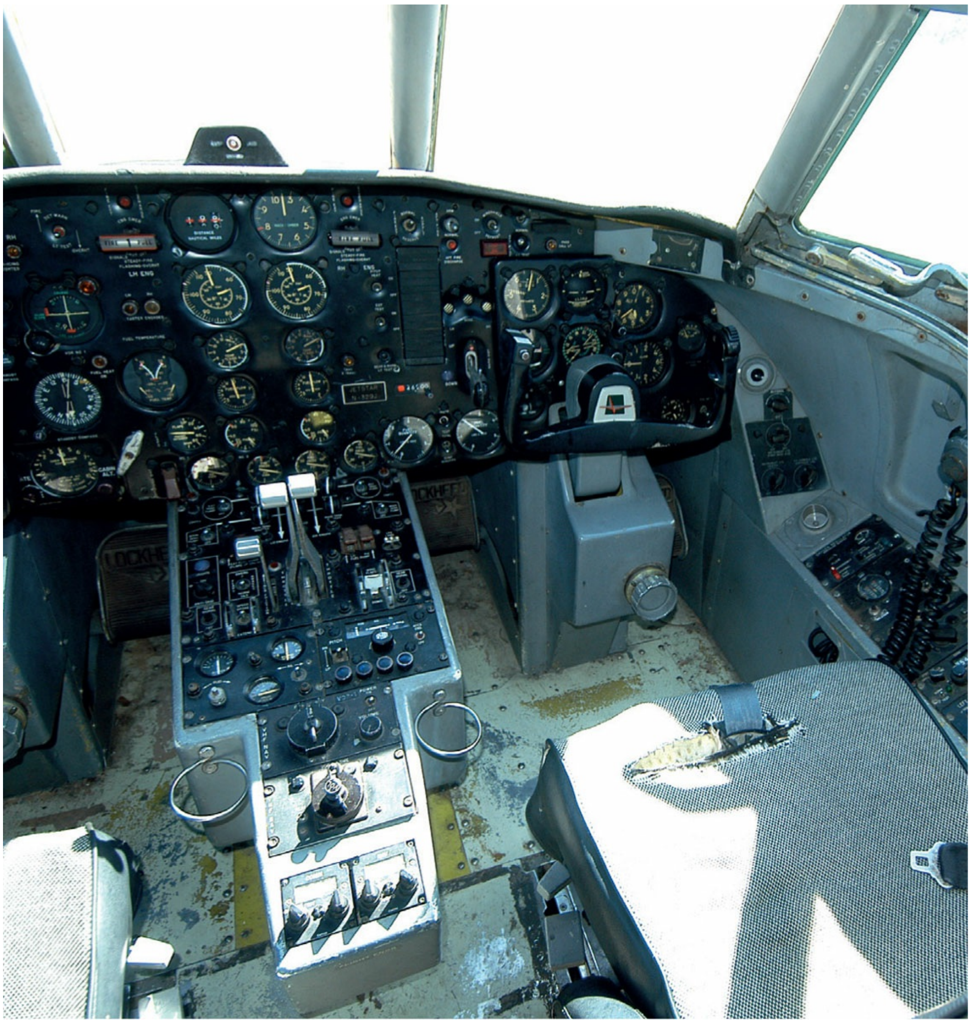
Kelly Johnson and the original JetStar flight-test and chase plane crews. From left to right: Robert Schumacher, co-pilot; Ernest L. Joiner, flight-test engineer; Kelly Johnson, designer; Jim Wood, USAF test pilot; Ray Goudey, Lockheed test pilot; and Tony LeVier, chief test pilot on the chase plane for the first flight. (Lockheed Martin)

JET Star
N329J
LOCKHEED
DOUGLA
AVY

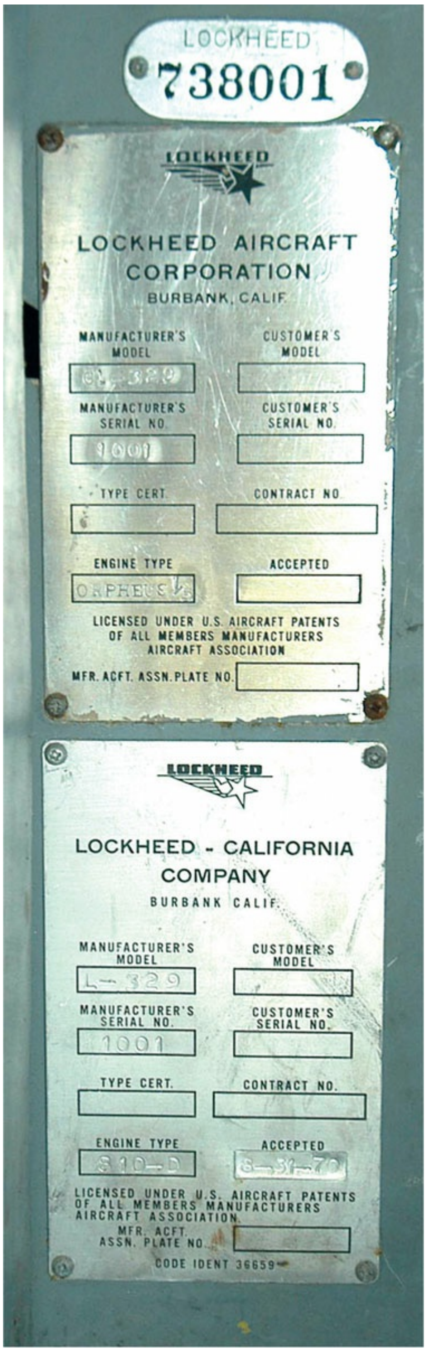
A year later it was photographed at another Edwards open house in May 1959. (Author's collection)

LOCKHEED
N329J

Skunk Works chief Kelly Johnson looks on as the prototype JetStar is prepped for a flight-test at Edwards AFB. (Lockheed Martin)



Prototype JetStar cockpit. (James C. Goodall)



LOCKHEED AIRCRAFT CORPORATION
BURBANK, CALIF.

MANUFACTURER'S MODEL: CL-329
CUSTOMER'S MODEL:
MANUFACTURER'S SERIAL NO.: 1001
CUSTOMER'S SERIAL NO.:
TYPE CERT.:
CONTRACT NO.:
ENGINE TYPE: ORPHEUS
ACCEPTED:

LICENSED UNDER U.S. AIRCRAFT PATENTS
OF ALL MEMBERS MANUFACTURERS
AIRCRAFT ASSOCIATION

MFR. ACFT. ASSN. PLATE NO.:

LOCKHEED - CALIFORNIA COMPANY
BURBANK CALIF.

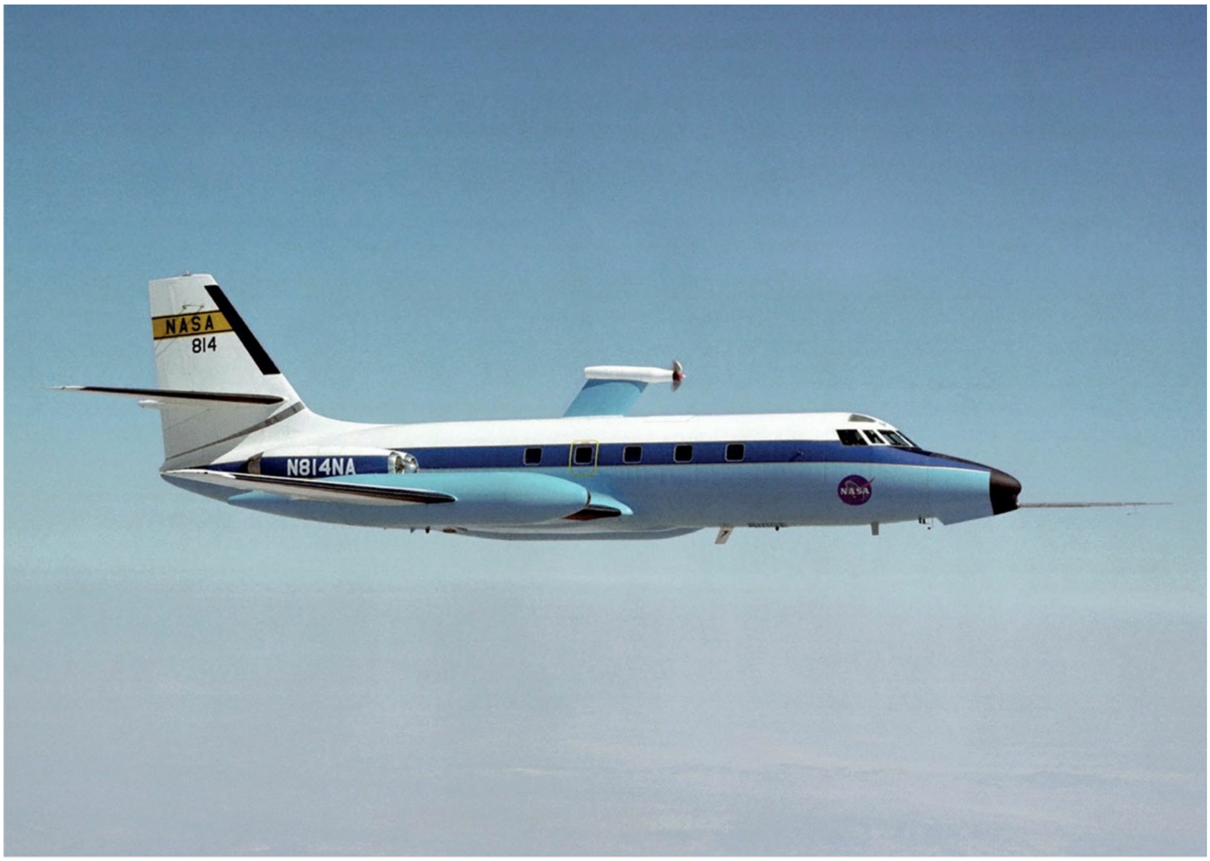
MANUFACTURER'S MODEL: L-329
CUSTOMER'S MODEL:
MANUFACTURER'S SERIAL NO.: 1001
CUSTOMER'S SERIAL NO.:
TYPE CERT.:
CONTRACT NO.:
ENGINE TYPE: 810-D
ACCEPTED: 8-31-70

LICENSED UNDER U.S. AIRCRAFT PATENTS
OF ALL MEMBERS MANUFACTURERS
AIRCRAFT ASSOCIATION.

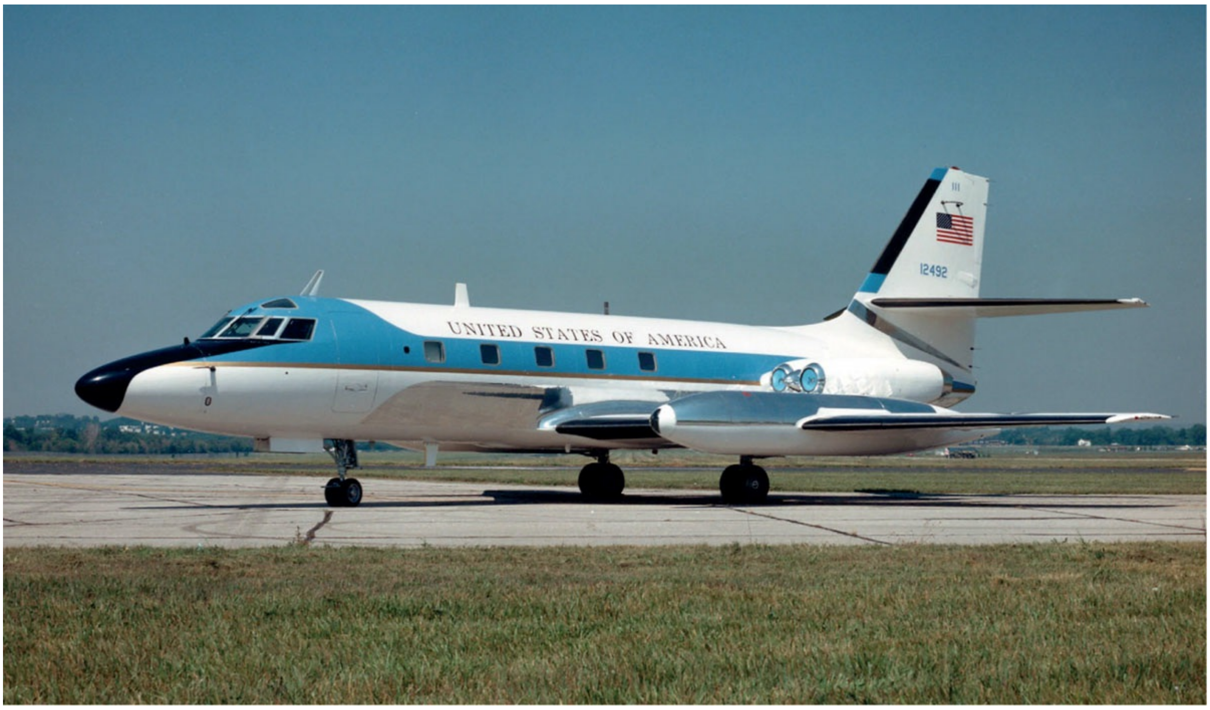
MFR. ACFT. ASSN. PLATE NO.:

CODE IDENT 36659

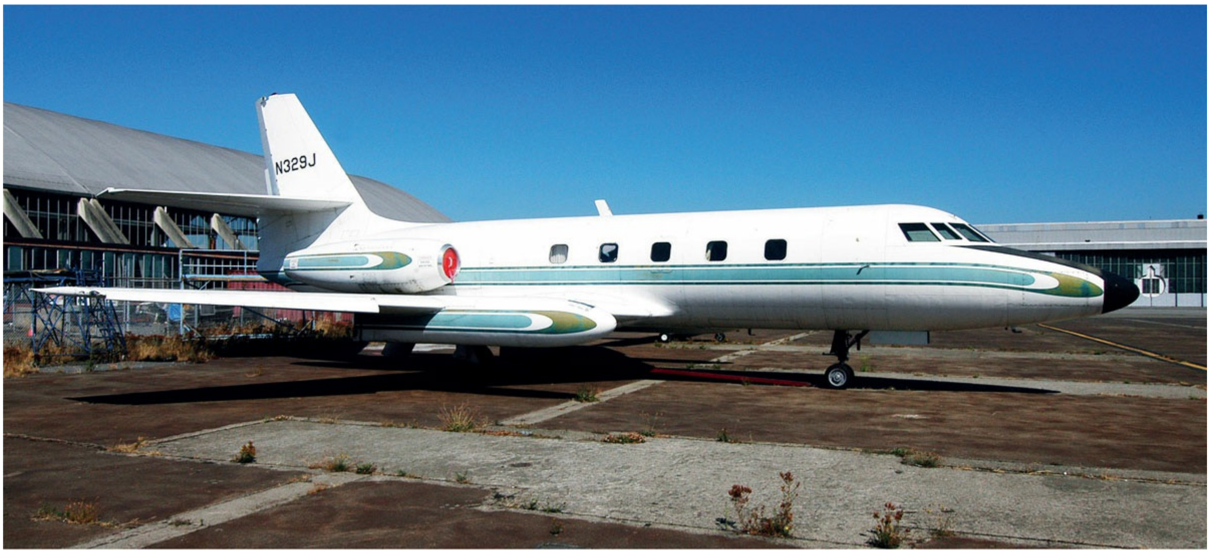
Prototype JetStar data plates. (James C. Goodall)



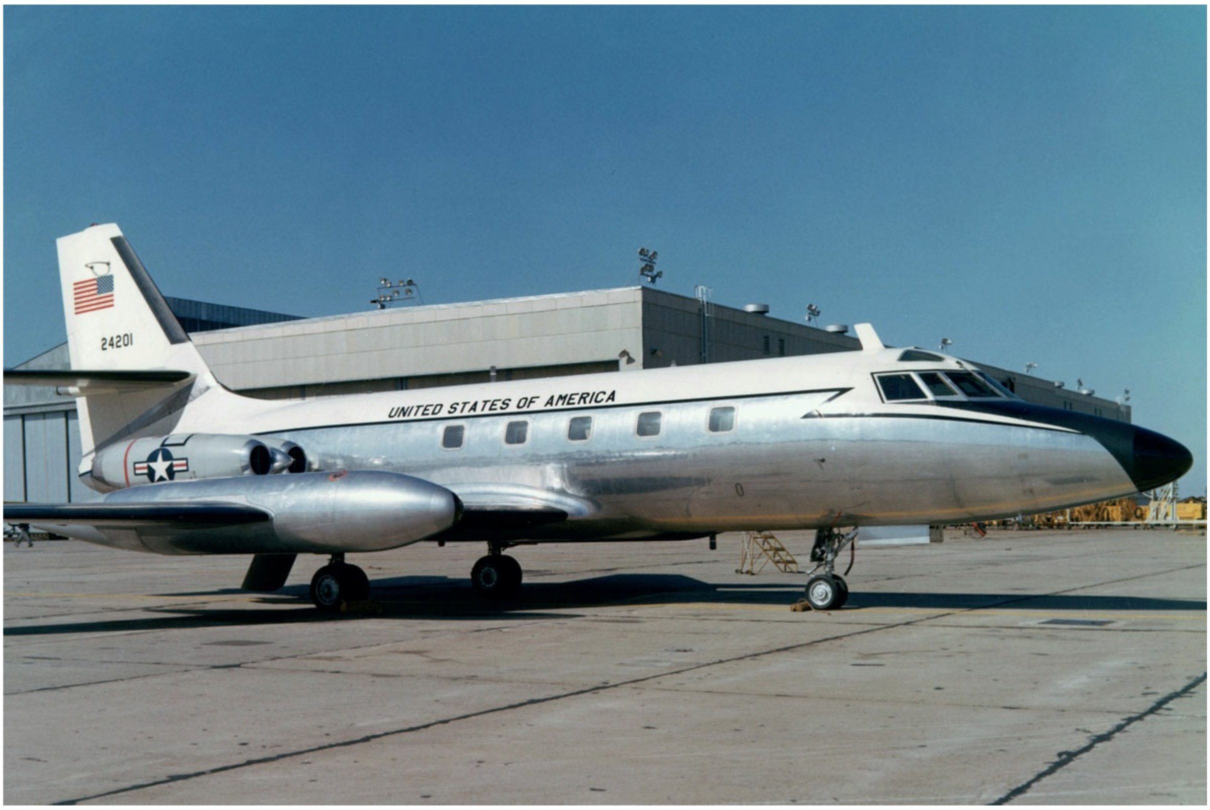
The NASA Dryden Research Center-based JetStar during testing of advanced propfan designs. Dryden conducted flight research in 1981–82 on several designs. The technology was developed under the direction of the Lewis Research Center (today the Glenn Research Center, Cleveland, OH) under the Advanced Turboprop Program. (NASA)



In 1961, the USAF acquired six Lockheed VC-140B JetStars to transport the President of the United States, high-ranking government officials and other heads of state. The VC-140B is the military version of the famous Lockheed JetStar business jet. (NMUSAF)



The prototype JetStar where it called home for almost 20 years, the British Colombia Institute of Technology, located at the Vancouver International Airport, BC, as it was prepped to be moved to the Museum of Flight's Restoration Facility at Paine Field, Everett, WA. (James C. Goodall)


24201
UNITED STATES OF AMERICA

The final Lockheed C-140B JetStar executive transport built for the USAF sits on the ramp in Marietta, prior to delivery on 3 July 1963. (Lockheed Martin)

SST L-2000

1958

PROGRAM: L-2000

Name: SST (Supersonic Transport)

Mission: Supersonic airliner

Length: 273ft 2in (83.26m)

Wing Span: 116ft (35.36m)

Height: 46ft (14m)

Max T.O. Weight: 590,000lb (267,600kg)

First Flight: Mockup only

Last Flight: N/A

Crew: Cockpit crew 4; cabin crew 8

Number Built: Mockup only

Power Plant: 4 x GE4/J5M or 4 x Pratt & Whitney JTF17A-21L

Design Speed: Mach 3.24 (2,150mph; 4,000km/h)

Service Ceiling: 76,500ft (23,317m)

Combat Radius: N/A

Weapons Load: N/A

Most of the major US aviation firms spent at least some time in the 1950s considering supersonic transport (SST) designs. Lockheed's first attempts date to 1958. Lockheed sought an airplane with cruise speeds of around 2,000mph with takeoff and landing speeds that compared to large subsonic jets of the same era. Early designs followed Lockheed's tapered straight wing, similar to the one used on the F-104 Starfighter, with a delta-shaped canard for aerodynamic trim. The problem was that in wind-tunnel tests the shift in the airplane's center of lift (C/L) was substantial.

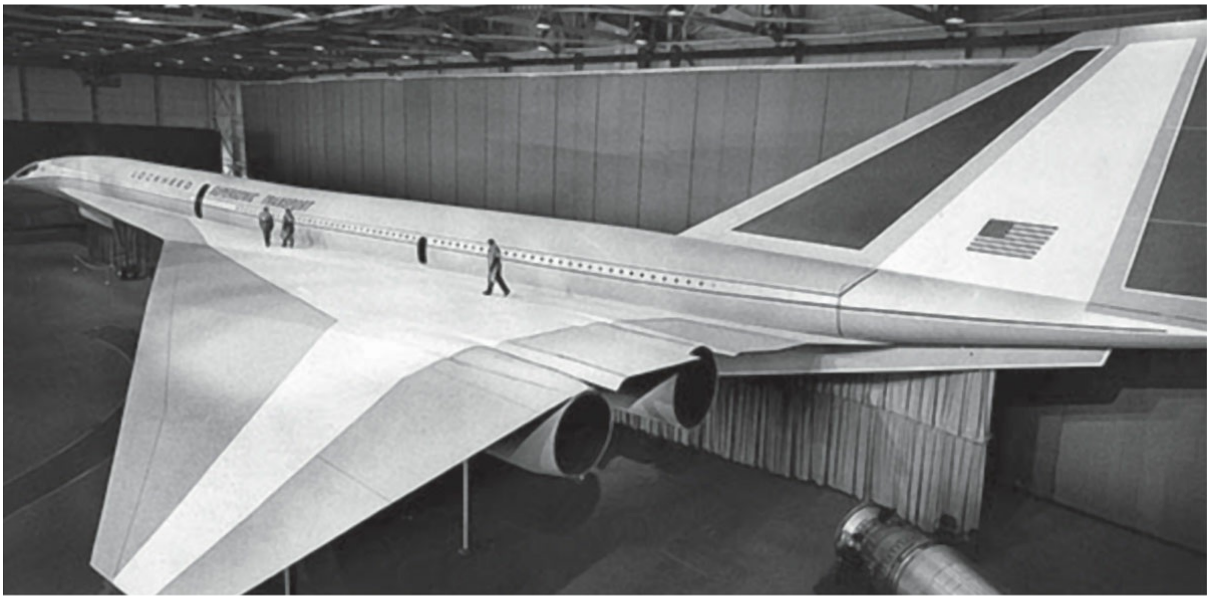
A delta wing was substituted which alleviated a portion of the movement, but it was not deemed sufficient. Lockheed knew that a variable-geometry, swing-wing design could accomplish this goal, but felt it was too heavy; they preferred a fixed-wing solution. In a worst-case scenario, they were willing to design a fixed-wing aircraft using fuel for ballast. By 1962 Lockheed had arrived at a highly swept, cranked-arrow design featuring four engine pods buried in the wings and a canard. The improvement was closer to their goal, but still not optimal. By 1963, they had extended the leading edge of the wing forward a bit to eliminate the need for the canard, and re-shaped the wing into a double-delta shape with a mild twist and camber. This, along with careful shaping of the fuselage, was able to control the shift in the center of pressure caused by the highly swept forward part of the wing developing lift supersonically. The engines were shifted from being buried in the wings to individual pods slung below the wings.

The new design was designated L-2000-1 and was 223ft long with a narrow-body 132in-wide fuselage to meet aerodynamic requirements, allowing for passenger seating of five abreast in coach and a four-abreast arrangement in first-class seating. A typical mixed-class seating layout would equal around 170 passengers, with high-density layouts exceeding 200 passengers.

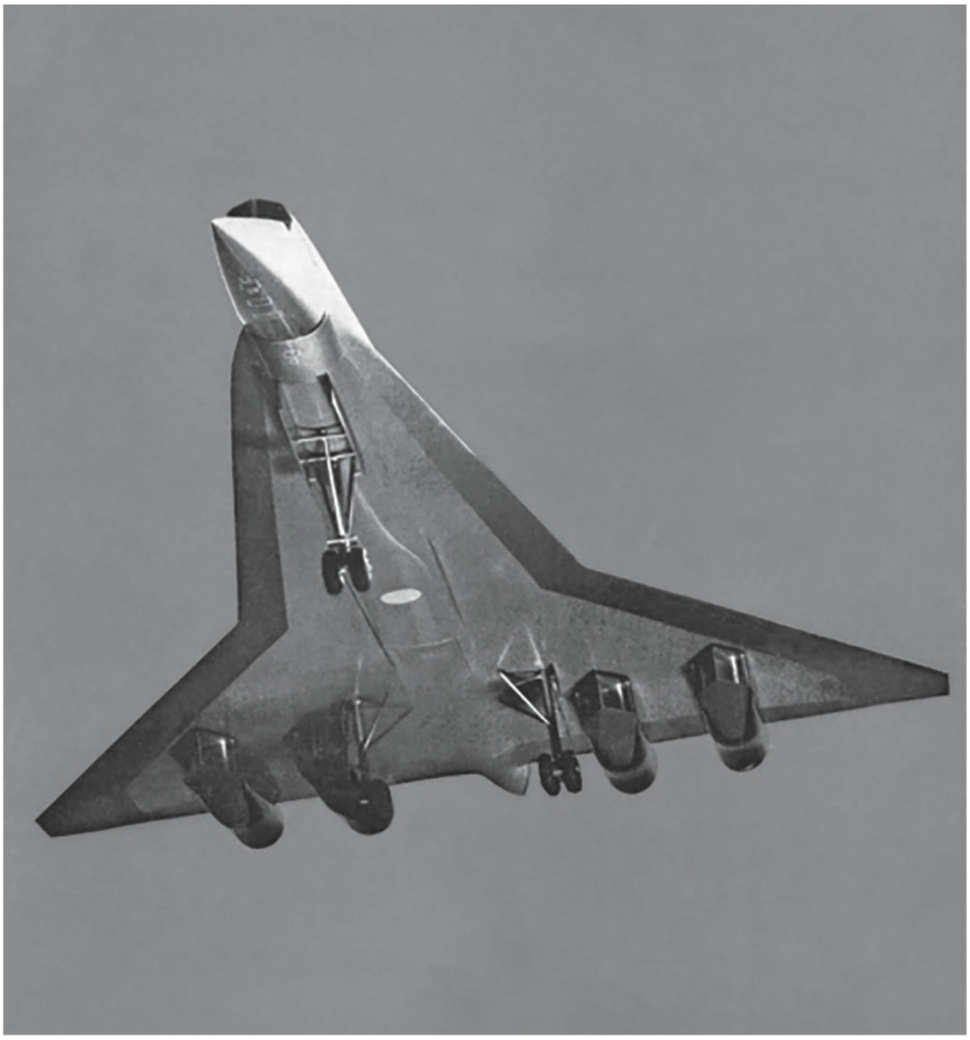
The L-2000-1 featured a long, pointed nose that was almost flat on top and curved on the bottom, which allowed for improved supersonic performance, and could be drooped for takeoff and landing to provide adequate visibility. The wing design featured a sharp forward inboard sweep of 80 degrees, with the remaining part of the wing's leading edge swept back 60 degrees. The high sweep angles produced powerful vortices on the leading edge which increased lift at moderate to high angles of attack, yet still retained stable airflow over the control surfaces during a stall. These vortices also provided good directional control, which was somewhat deficient with the nose drooped at low speeds. The wing, with a thickness-to-chord ration of only 3 percent, provided substantial lift due to its large area, which, aided by vortex lift, allowed takeoff and landing speeds comparable to a Boeing 737. Additionally, a delta wing is a naturally rigid structure which requires little stiffening.

By 1966, the design took on its final form as the L-2000-7A and L-2000-7B. The L-2000-7A featured a re-designed wing and fuselage lengthened to 273ft. The longer fuselage allowed for a mixed-class seating of 230 passengers. Unlike previous versions, this aircraft featured a leading-edge flap to increase lift at low speeds, and to allow a slight down-elevon deflection. The fuselage, as a result of greater length, changes to the wing design and attempts to further reduce drag, featured a slight vertical thinning where the wings were, a more prominent wing/body “belly” to carry fuel and cargo, a longer nose and a refined tail. Since the airplane was not as directionally stable as before, the plane boasted a ventral fin, located on the underside of the trailing fuselage. The L-2000-7B was extended to 293ft, utilizing a lengthened cabin and a more pronounced upward-curving tail to reduce the chance of the tail striking the runway during over-rotation. Both designs had the same maximum weight of 590,000lb, and the aerodynamic lift-to-drag ratio was increased to 8:1.

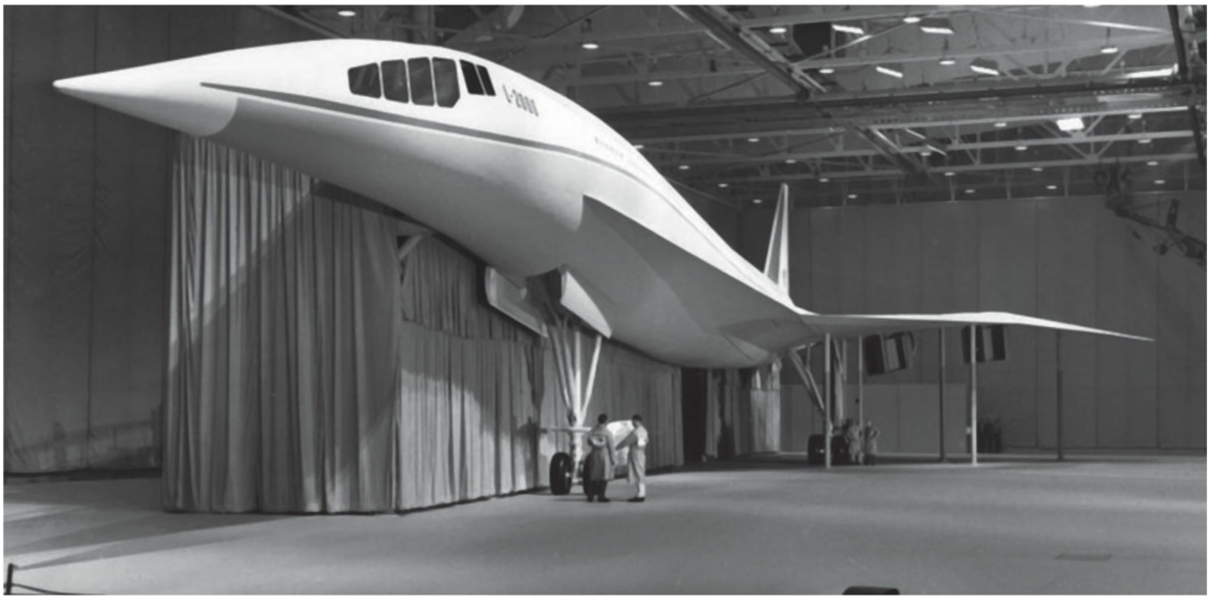
Full-scale mockups of the Boeing 2707-200 and L-2000-7 designs were presented to the Federal Aviation Administration (FAA), and on 31 December 1966 the Boeing design was selected. The Lockheed design was judged simpler to produce and less risky, but its performance during takeoff and at high speed was slightly lower. Because of the JTF-17A, the L-2000-7 was also predicted to be louder. The Boeing design was considered more advanced, representing a greater lead over the Concorde and thus more fitting to the original design mandate. Boeing eventually changed its advanced variable-geometry wing design to a simpler delta-wing similar to Lockheed’s design, but with a tail. If Lockheed had built its simpler design, it might have flown by 1971. With technical problems, delays, cost overruns, and environmental and economic concerns, the Boeing SST was ultimately canceled on 20 May 1971 after the US Congress stopped federal funding for the SST program on 24 March.



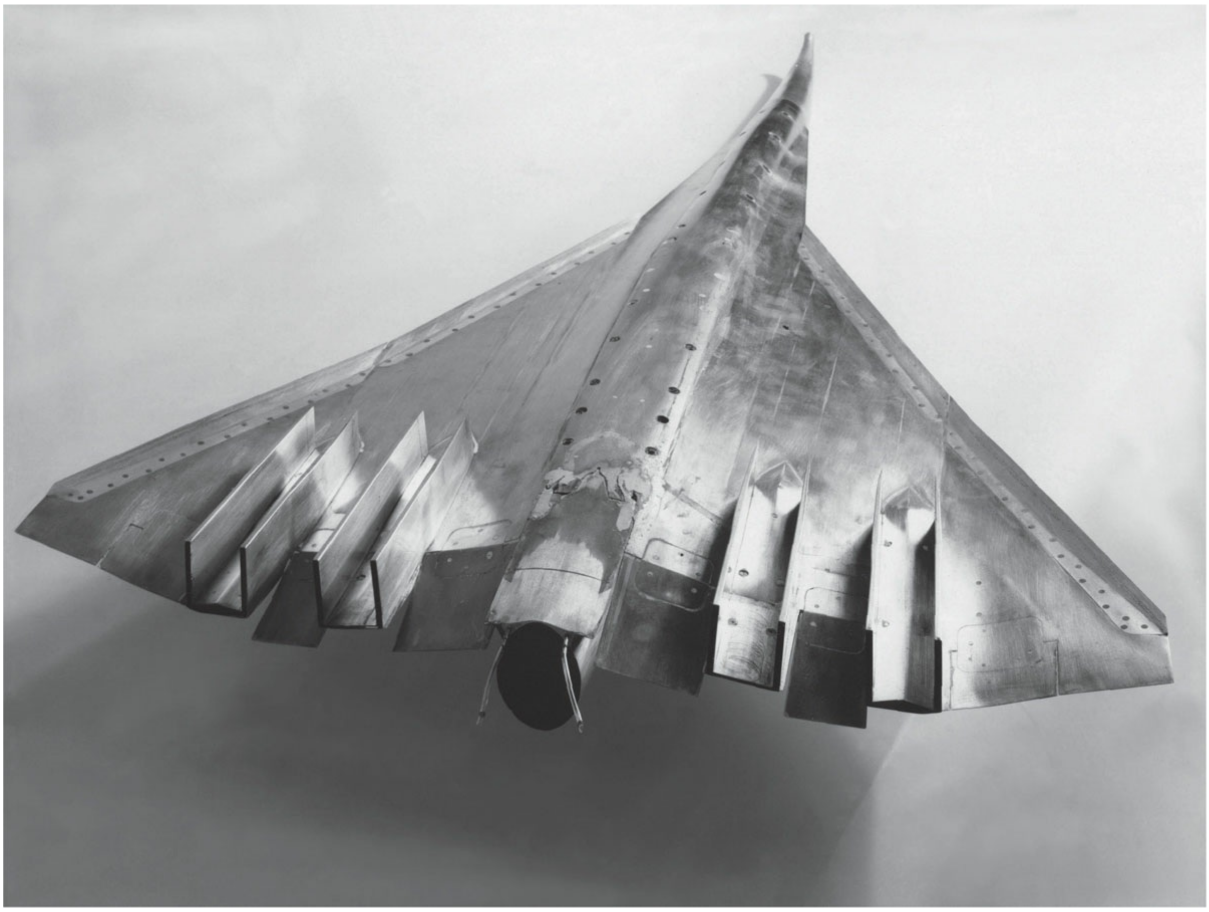
On 27 June 1966, three Lockheed technicians walk on the port side delta wing of the full-scale mockup of the proposed Lockheed supersonic transport that stretches 273ft from nose to tail. (Lockheed Martin)



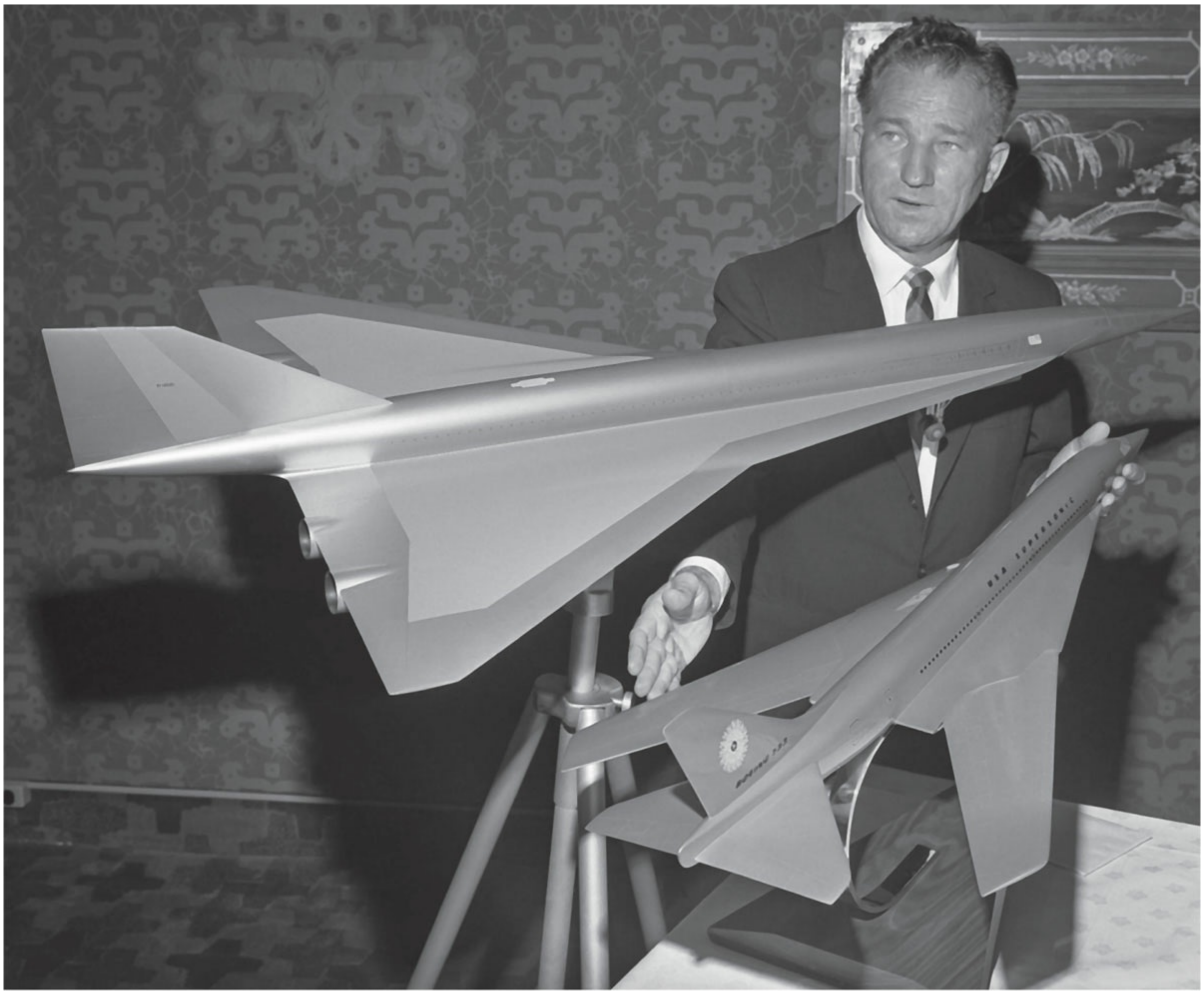
A wind tunnel model of the proposed Lockheed L-2000 as viewed from the bottom looking up. (Lockheed Martin)



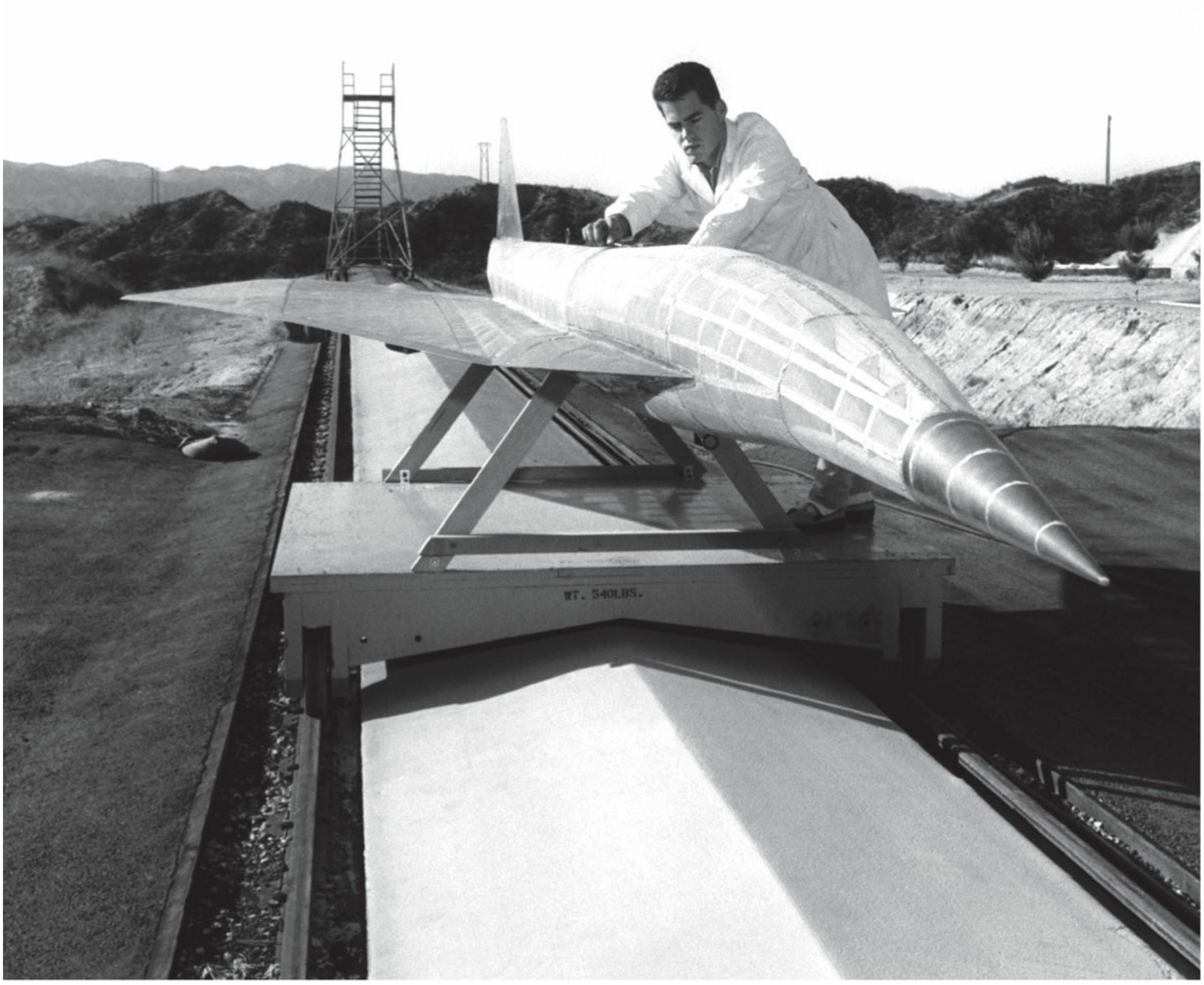
A front-on view of the full-scale mockup of the proposed Lockheed model L-2000 SST. (Lockheed Martin)



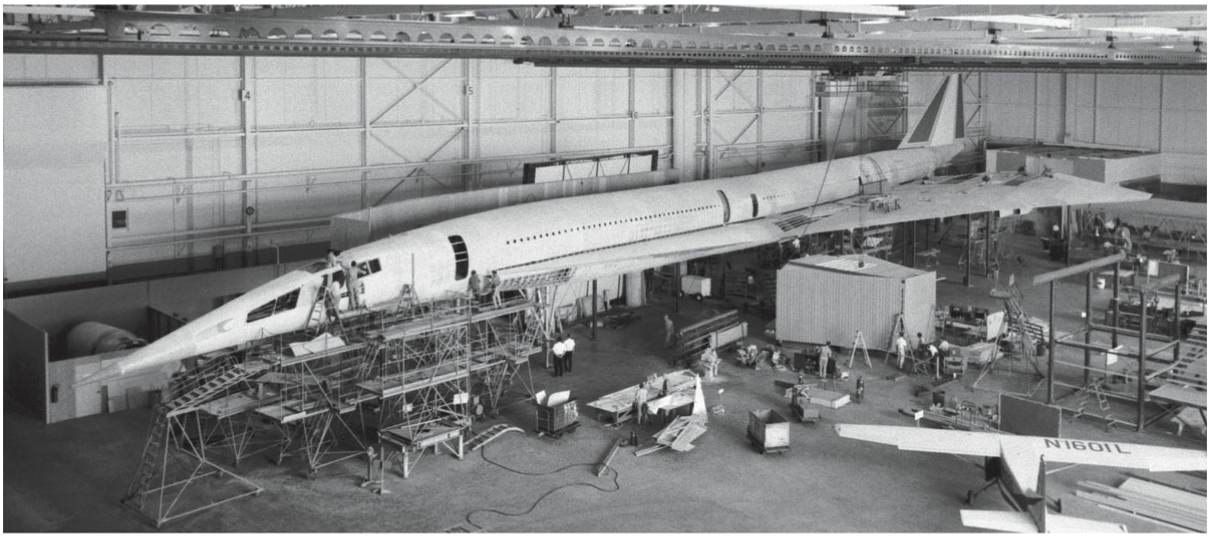
One sampling of several different and varied wind tunnel configurations. (Lockheed Martin)



On 13 July 1964, Federal Aviation Agency (FAA) test pilot Joe Tymczyszyn displays models of Lockheed, top, and Boeing, bottom, supersonic transport planes. (Lockheed Martin)



A Lockheed technician checks out the scale model of the proposed Lockheed SST on a highspeed test sled. (Lockheed Martin)

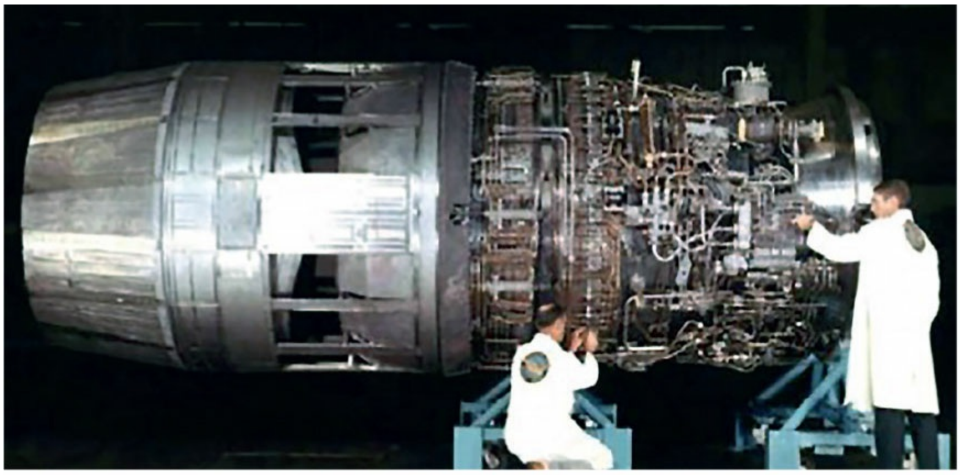


The buildup of the fullscale mockup of the proposed Lockheed SST at the Lockheed production facility at the Hollywood Burbank Airport. (Lockheed Martin)

LOCKHEED
SUPERSONIC TRANSPORT
L-2000

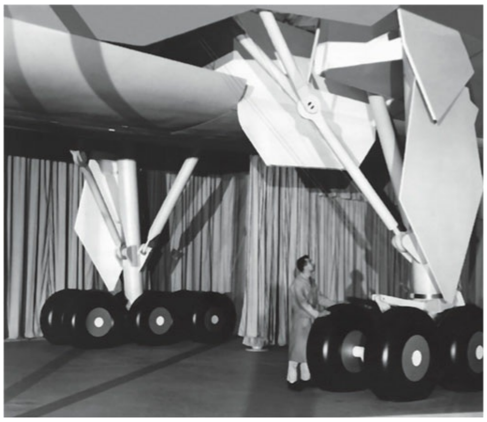
You get an idea of just how big the Lockheed SST would have been if it had ever gone into production. (Lockheed Martin)

Lockheed L-2000 SST cabin interior. (Lockheed Martin)

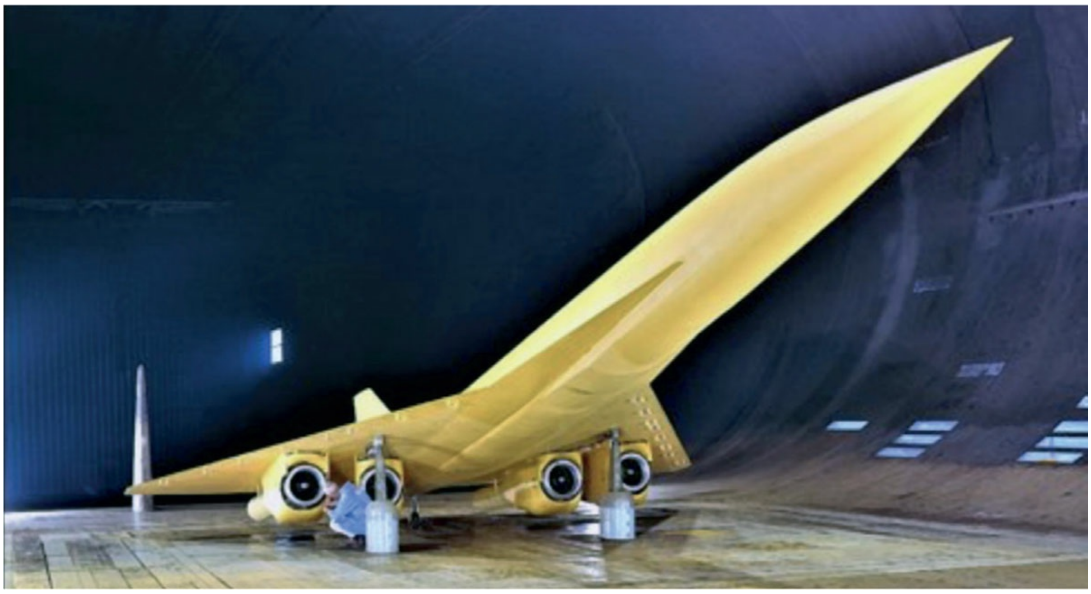


One of the proposals for powering the Lockheed SST was to use four modified Pratt

& Whitney J58 turbo ramjets for power. If this had gone forward, the noise of four J58s, would not have been twice but three times as loud and would have never made the noise requirements of the late 20th century. (Lockheed Martin)



The stunning overall view of the main landing gear on the proposed Lockheed SST. Just think of the fun it would be to load cargo and passengers' luggage. (Lockheed Martin)



Lockheed proposed two L-2000 versions, the L-2000-7A, an intercontinental model for up to 266 passengers and the slightly larger, 308-passenger L-2000-7B. The Fixed Wing Supersonic Transport is shown in the Ames 40 x 80ft wind tunnel. The three-quarter front view of the Lockheed SST with leading edge flaps deflected is shown in this 13 May 1965 photo. (Lockheed Martin)

XV-4A/B HUMMINGBIRD

1962

PROGRAM: XV-4A/B

Name: Hummingbird

Mission: Vertical take off and landing (VTOL)

Length: 32ft 8in (9.96m)

Wing Span: 25ft 8in (7.82m)

Height: 11ft 9in (3.58m)

Max T.O. Weight: 7,200lb (3,266kg)

First Flight: 7 July 1962

Last Flight: XV-4A lost on 10 June 1964; XV-4B lost on 14 March 1969

Crew: 2

Number Built: 2

Power Plant: 2 x Pratt & Whitney JT12A-3LH turbojets

Design Speed: Mach 0.68 (518mph; 834km/h)

Service Ceiling: 12,000ft (3,657.6m)

Combat Radius: 600 miles (521nm; 966km)

Weapons Load: N/A

The Lockheed XV-4 Hummingbird (originally designated VZ-10) was a US Army project to demonstrate the feasibility of using vertical takeoff and landing (VTOL) for a surveillance aircraft carrying target-acquisition and sensory equipment. It was designed and built by the Lockheed Corporation in the 1960s, one of many attempts to produce a V/STOL (Vertical and/or Short Takeoff and Landing) jet. Both prototype aircraft were destroyed in accidents.

Vertical takeoff lift was obtained by exhausting the engine flow downward through multiple nozzles, augmented by a secondary flow of cold air. But the performance was far below estimates with only a 1.04 thrust-to-weight ratio, and the prototype crashed on 10 June 1964, killing the pilot. The second aircraft was converted to lift jets instead, yet also crashed after several tests.

None of the early American V/STOL designs would result in a production aircraft. The British Hawker Siddeley Harrier used vectoring nozzles, while the Russian Yakovlev Yak-38 Forger attack jet used lift jets in conjunction with rotating rear nozzles.

The first conventional takeoff flight of the first prototype, XV-4A, 624503, took place on 7 July 1962. Initial tethered flight-tests were carried out on 30 November 1962 with the first free-hovering flight occurring on 24 May 1963. The first flight to transition from hovering to forward flight took place on 8 November 1963. XV-4A 62-4503 was destroyed in the fatal crash in Cobb County, Georgia, on 10 June 1964.

Lockheed modified the second prototype aircraft between 1966 and 1968 to XV-4B standard and its first flight was on 4 June 1968. The two Pratt & Whitney JT12 engines were replaced with six General Electric J85s, four of these units acting as lift jets.

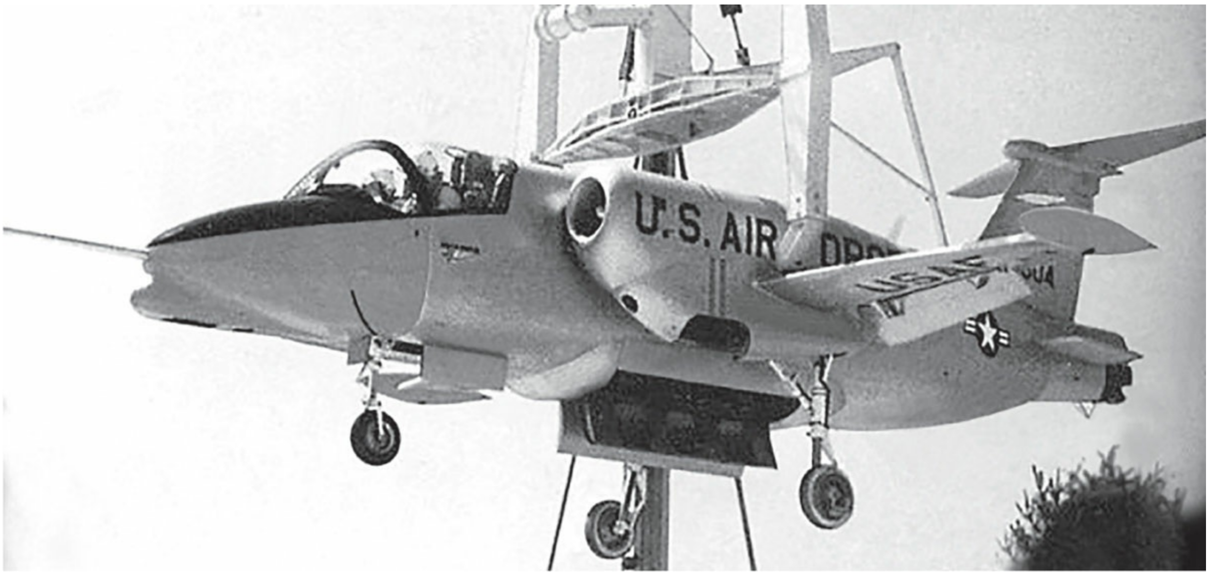
Just like the XV-4A, the XV-4B used vertical takeoff and landing systems (VTOL) as well as conventional flight methods. Upon takeoff the aircraft weighed 7,200lb. The wing span was 25ft 8in, and it had a top speed of 518mph, with a cruising speed of 391.5mph. It had a range of 600 miles, and was able to climb at a rate of 12,000ft/minute. The XV-4B was 34ft long. The heaviest part of the plane was the propulsion system, which weighed in at 3,231lb. The fuel tanks were located internally, with boost pumps and jet ejectors, along with the associated valves. The tanks were located in the front of the fuselage and could hold a total of 740 gallons of aviation turbine fuel. Because of the forward position of the tanks, fuel had to be consumed evenly. An imbalance in the fuel tanks of over 100 gallons ran the risk of destabilizing the aircraft. The initial service life of the aircraft was intended to be 500 hours, but the aircraft crashed in Georgia on 14 March 1969 during testing, long before the designated goal; pilot Harlan J. Quamme escaped uninjured, using the ejection seat.

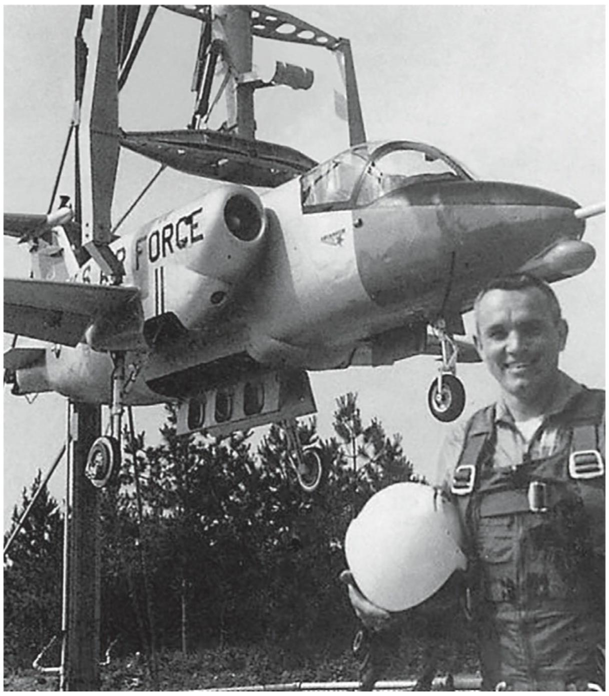
The XV-4B was significantly different than the XV-4A in its internal design. The differences were found in the wings, fuselage, landing gear, power plant installations, hydraulics and controls. The XV-4B contained two reaction control valves as a failsafe for the engine. One major change was the addition of four turbojet engines faced vertically on the fuselage. This provided massive amounts of vertical thrust for VTOL flight. The addition of a stability augmentation system (SAS), along with hydro-mechanical clutches and feel springs, gave the pilot a good feel on the controls and more ability to control the aircraft. The rudder included a new centering spring above the feel spring to reduce friction on the rudder. The primary flight control system (PFCS) was a hybrid fly-by-wire system along with conventional flight controls as a backup.

No fuel was carried in the wings, even though the wings had the basic box-beam structure. It had 2 degrees of freedom in the pitch and sideslip, whereas the rolls only had 1 degree of freedom. Each engine contained a diverter valve. These valves ducted either longitudinally into the horizontal thrust nozzles of the aircraft, or inward to the lift nozzles located in the fuselage. The lift/cruise engines provided forward thrust when faced horizontally and lift when faced vertically. This was through the use of the diverter valves. All six tail pipes had 10 degrees of freedom in order to direct thrust. The fuselage engines were used when initiating VTOL flight but were turned off when the aircraft was sufficiently in flight.

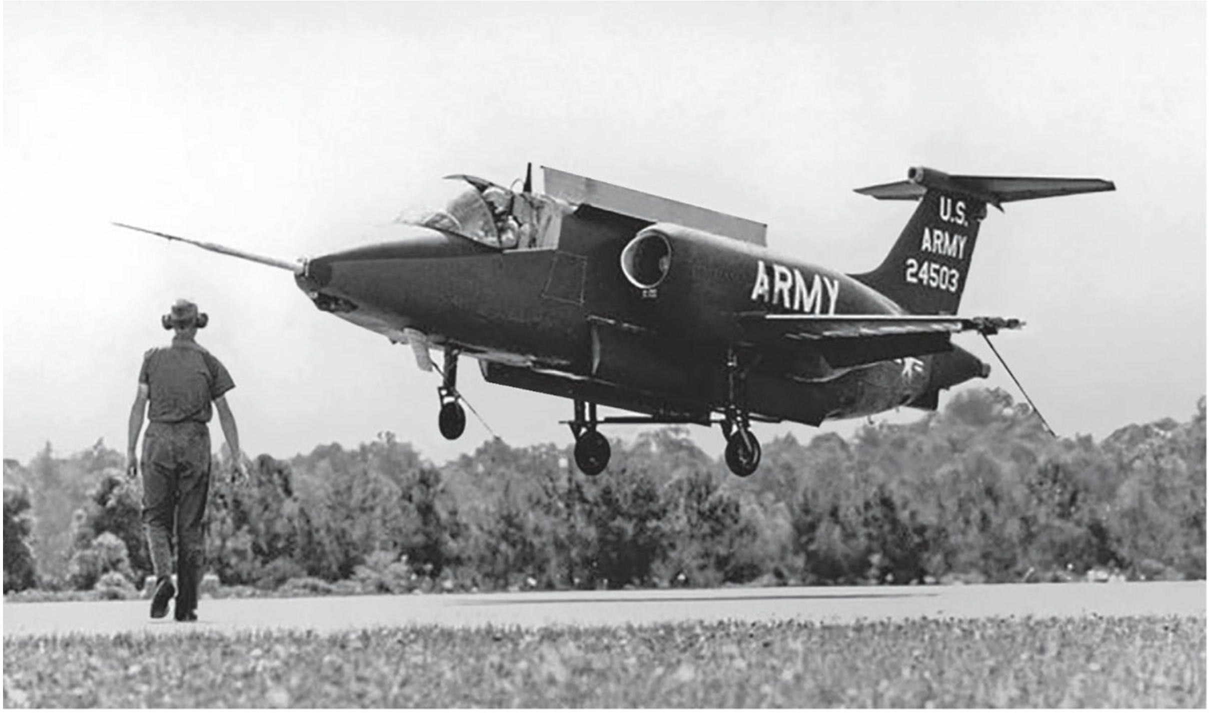
U.S. AIR FORCE
24504

The second XV-4 was built as the XV-4B, seen early in its flight-test life. The XV-4 was an Army project designed and built by Lockheed in the early 1960s, one of many attempts to build a vertical takeoff and landing jet. (Lockheed Martin)





Two views of the XV-4B in the hover test fixture. (Lockheed Martin)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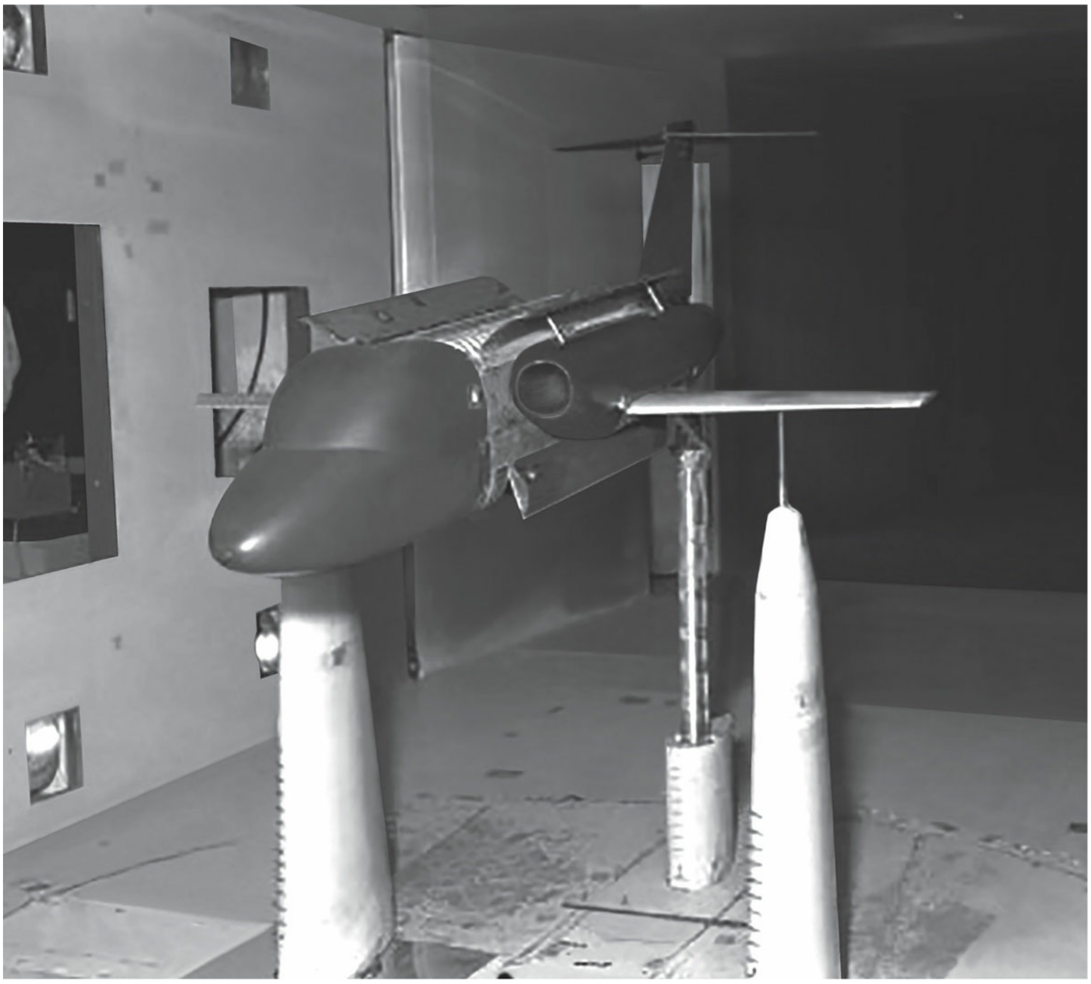
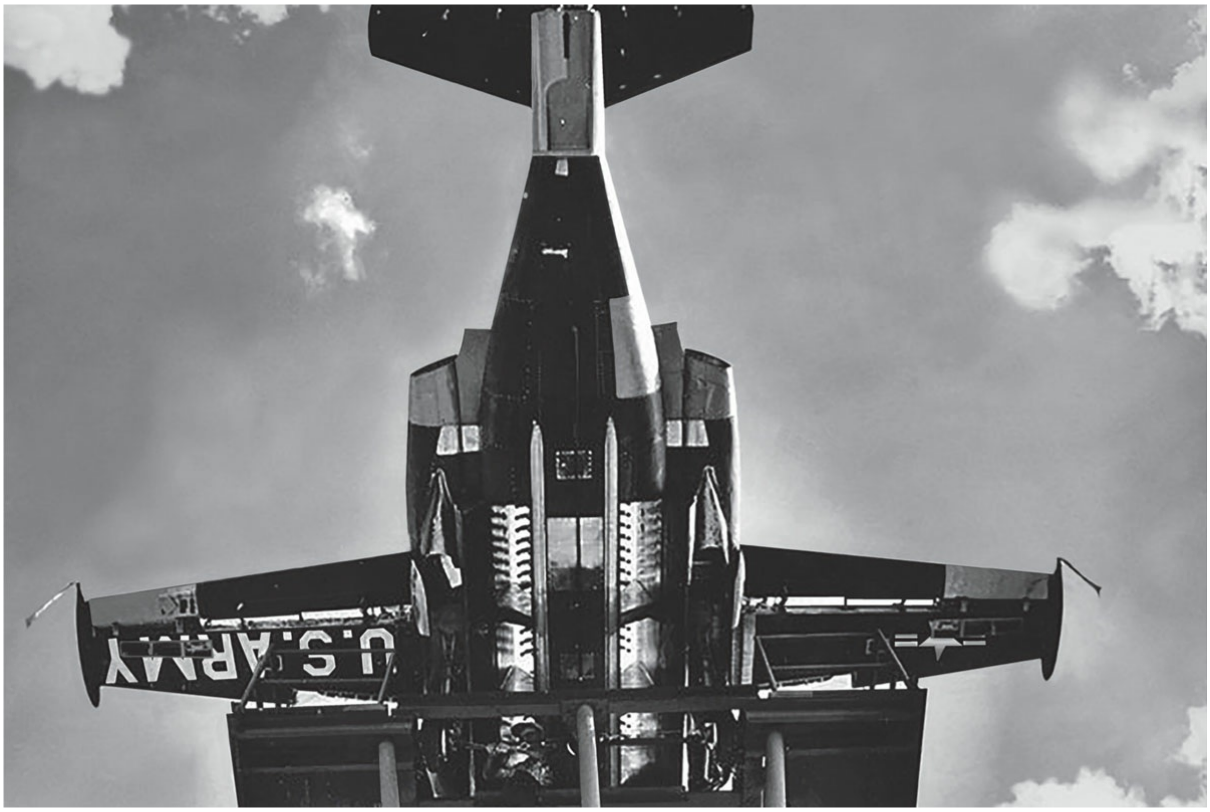
ARMY

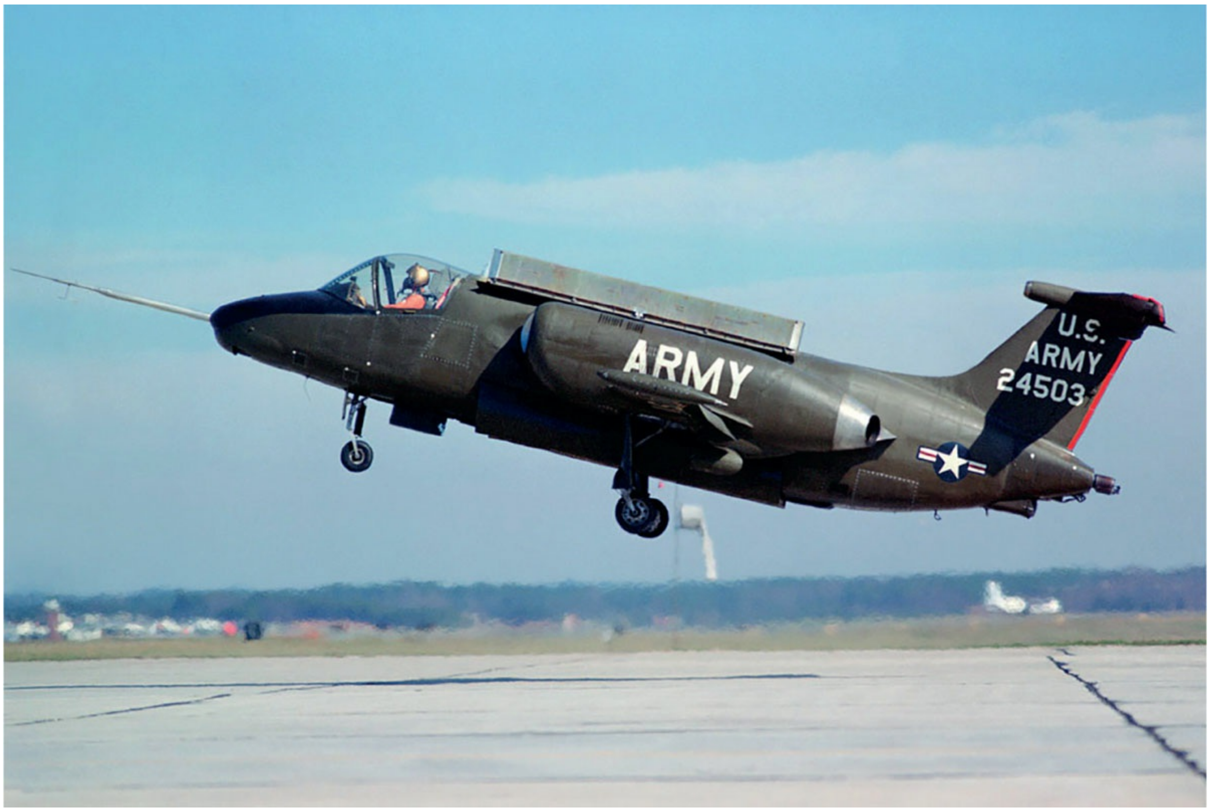
The XV-4A in hover mode as the ground crew watches for problems or unsafe conditions. (Lockheed Martin)



A sub-scale model of the XV-4 taken at the NASA Lewis Research Center in Cleveland, OH. (Lockheed Martin)



A bottom view of the first XV-4A in an engine runup fixture. (Lockheed Martin)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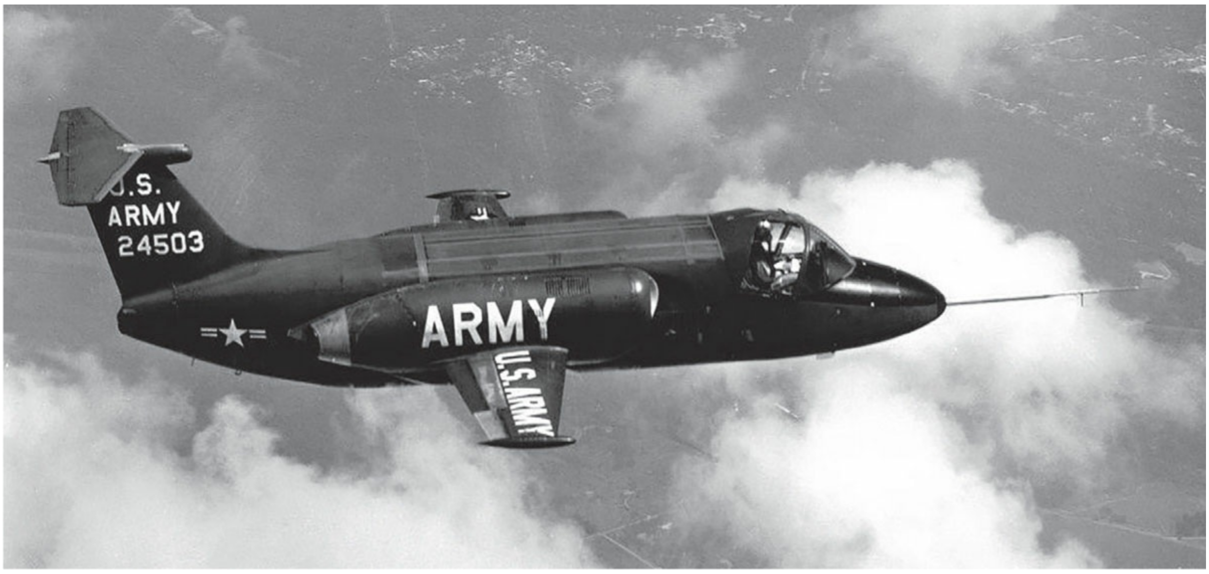
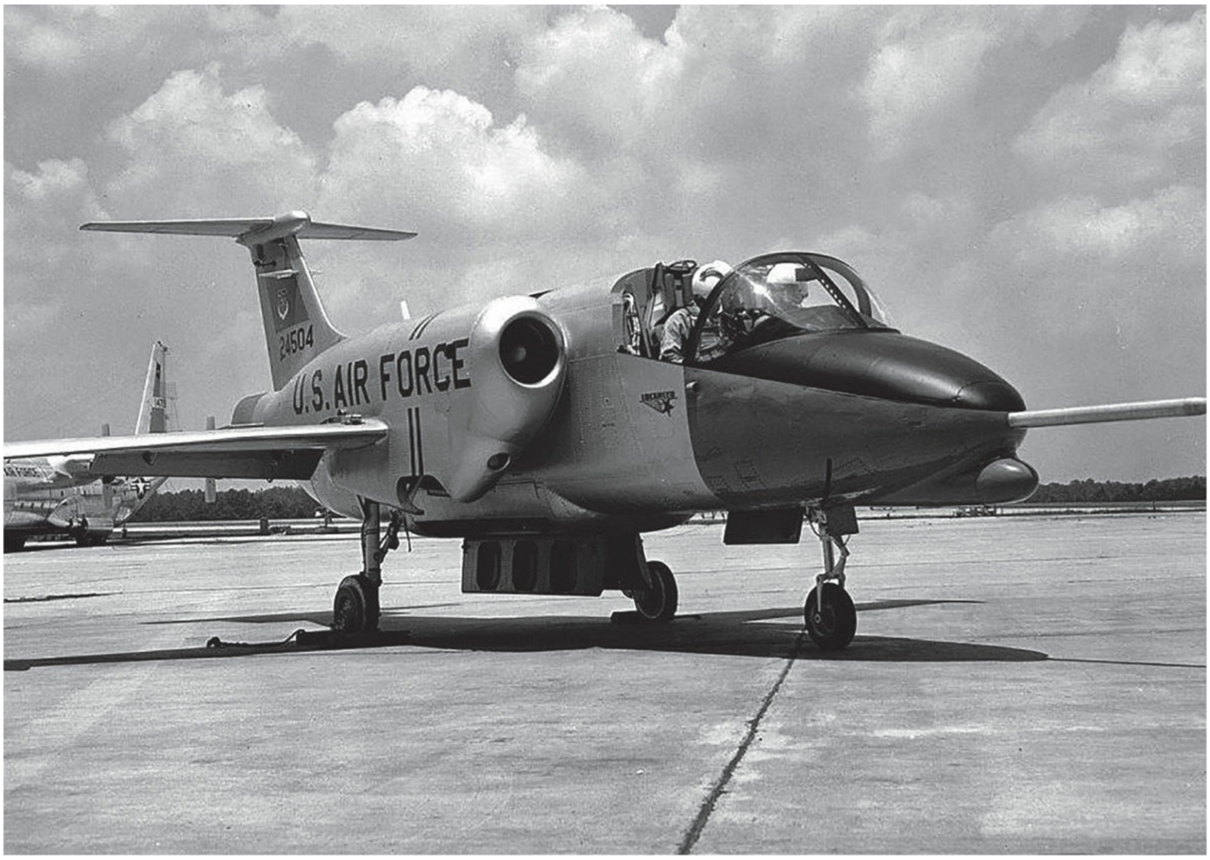
The first conventional takeoff of the first prototype, XV-4A 62-4503, took place on 7 July 1962 at the Lockheed Marietta plant near Atlanta, GA, in Cobb County. (Lockheed Martin)



The first transition from hover to forward flight took place on 8 November 1963 in the XV-4A. The first prototype XV-4A was destroyed in the crash in Cobb County on 10 June 1964. (Lockheed Martin)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U.S. AIR FORCE

The remaining XV-4B is shown on the ground with the canopy removed to help with evacuations in case of a hard landing mishap. (Lockheed Martin)

CL-400 SUNTAN

1962

PROGRAM: CL-400

Name: Suntan

Mission: Strategic reconnaissance

Length: 154ft 10in (47.19m)

Wing Span: 83ft 9in (25.5m)

Height: 30ft (9.1m)

Max T.O. Weight: 689,995lb (312, 976kg)

First Flight: Proposal only

Last Flight: N/A

Crew: 4

Number Built: Paper airplane

Power Plant: 1 x Pratt & Whitney Model 304-2

Design Speed: Mach 2.5 (1,918mph; 3,087km/h)

Service Ceiling: 95,000ft (28,956m)

Combat Radius: 2,528 miles (2,200nm; 4,070km)

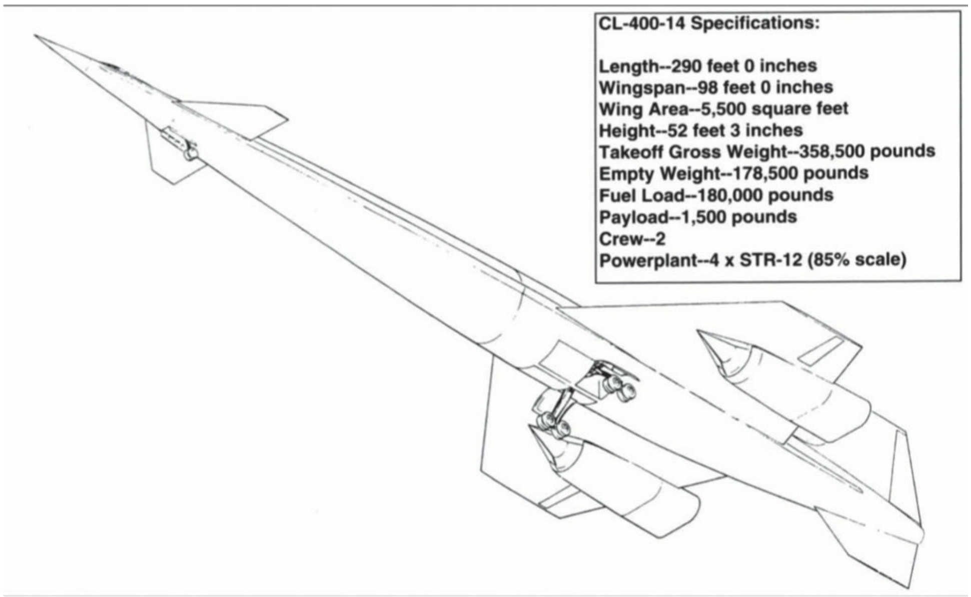
Weapons Load: Cameras, electronic countermeasures (ECM) and defensive systems (DEF)

The largest and most extraordinary project for using hydrogen as a fuel was carried out by the Air Force in 1956–58 in super secrecy. Very few people are aware of it, even now, yet over $100 million were spent – perhaps as much as $250 million. Although the project was canceled before completion, it led directly to the first rocket engine that flew using hydrogen. The project was codenamed Suntan, and even this was kept secret. It had all the air of cloak and dagger melodrama and indeed its principal precursor was just that. Suntan was an effort by the Air Force to develop a hydrogen-fueled airplane with performance superior to the secret spy plane, the U-2.

Suntan had its roots in Air Force interest in very high-altitude flight during the first half of the 1950s. One approach, along conventional lines, was pushed by Maj John D. Seaberg of the Wright Air Development Center, beginning in late 1952. This involved a modification of the Martin RB-57 and the start of the Bell X-16, although the latter was canceled in mid-1955. A different approach, sparked by a proposal by Randolph Rae in 1954 to build a glider-like airplane powered by the Rex engine, focused on the potential advantages of using liquid hydrogen. The Air Force interest in hydrogen was supported by Abe Silverstein, associate director of the Lewis Laboratory of the National Advisory Committee for Aeronautics (NACA).

By the end of 1955, the Air Force had in progress a number of research and development activities on the feasibility of using liquid hydrogen in flight. The Garrett Corporation, which bought Rae's patents and formed a Rex division with Rae as chief engineer, was three months into a contract for design studies of Rex engines and had concentrated on the largest and latest, the air-breathing Rex III. Kelly Johnson's Skunk Works at Lockheed Aircraft Corporation, past its peak effort in designing and building prototype U-2s for the CIA, was two months into a three-month design study of hydrogen-fueled aircraft for Garrett. United Aircraft (now United Technologies) was in the second quarter of a study of using hydrogen in a conventional turbojet engine, and a competitor, General Electric, was also showing interest in hydrogen. Beech Aircraft and Garrett were investigating liquid hydrogen tanks, insulation, and behavior of hydrogen in storage. The Air Force and NACA agreed that the Lewis laboratory would determine the feasibility of flying an airplane fueled with liquid hydrogen. The Air Force would provide the estimated $1 million needed, as well as lend equipment.

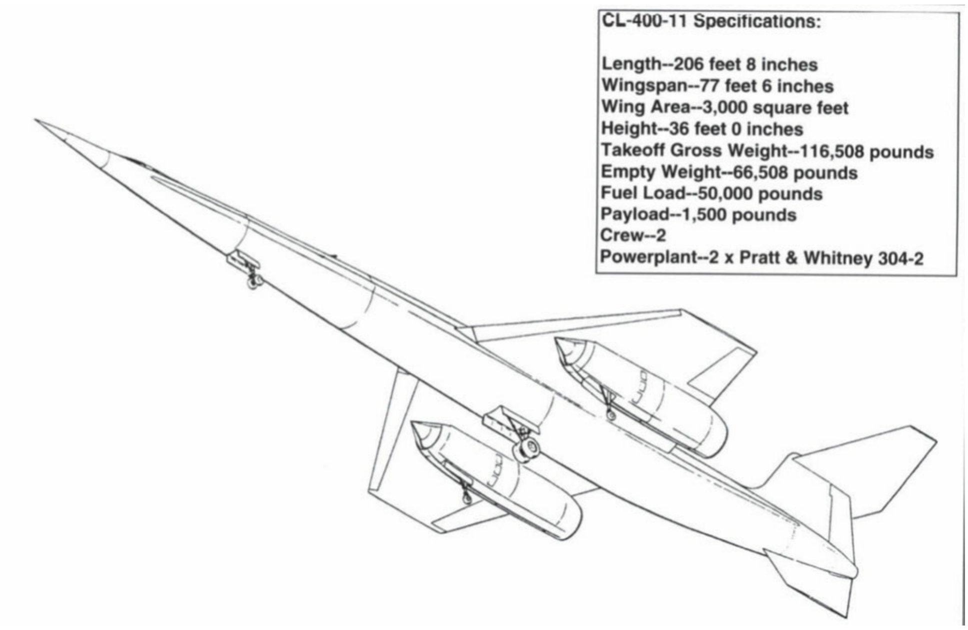
Dissatisfied with its supporting role to the CIA, the Air Force sought not only to take over the operational phase of the U-2 but also to regain the initiative in equipment by developing a second-generation airplane. One prospect was the Rae–Garrett proposal, but that approach did not seem quite the right answer. In late 1955, the time was ripe for a new proposal, and soon one was made by Kelly Johnson. He was immediately seen as the right man with the right idea.



CL-400-14 Specifications:

Length--290 feet 0 inches
Wingspan--98 feet 0 inches
Wing Area--5,500 square feet
Height--52 feet 3 inches
Takeoff Gross Weight--358,500 pounds
Empty Weight--178,500 pounds
Fuel Load--180,000 pounds
Payload--1,500 pounds
Crew--2
Powerplant--4 x STR-12 (85% scale)

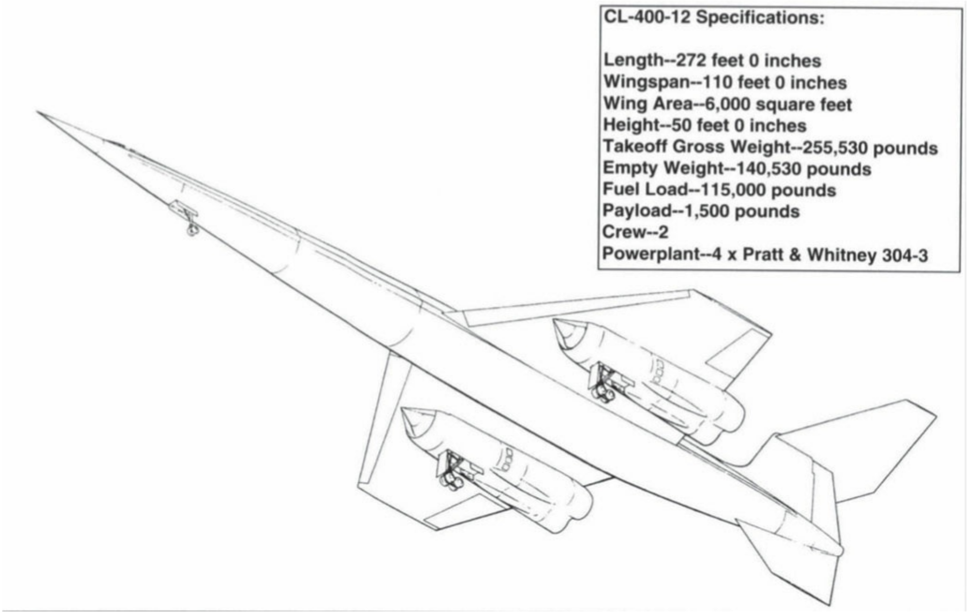
The CL-400-14 specification. (Lockheed Martin)



CL-400-11 Specifications:

Length--206 feet 8 inches
Wingspan--77 feet 6 inches
Wing Area--3,000 square feet
Height--36 feet 0 inches
Takeoff Gross Weight--116,508 pounds
Empty Weight--66,508 pounds
Fuel Load--50,000 pounds
Payload--1,500 pounds
Crew--2
Powerplant--2 x Pratt & Whitney 304-2

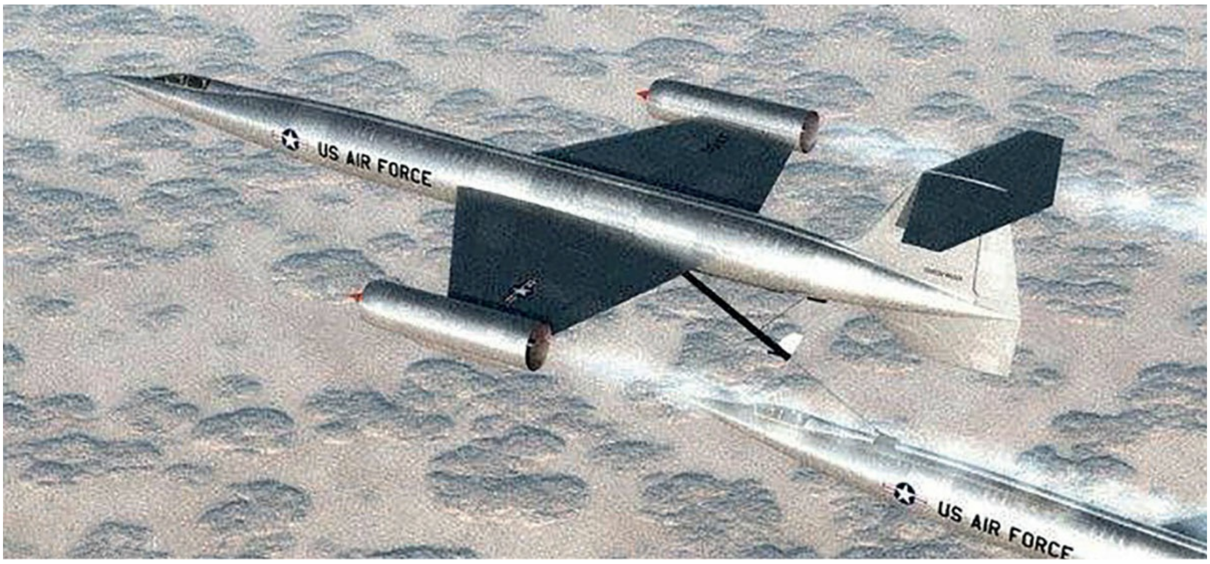
A drawing of the CL-400-11. (Lockheed Martin)



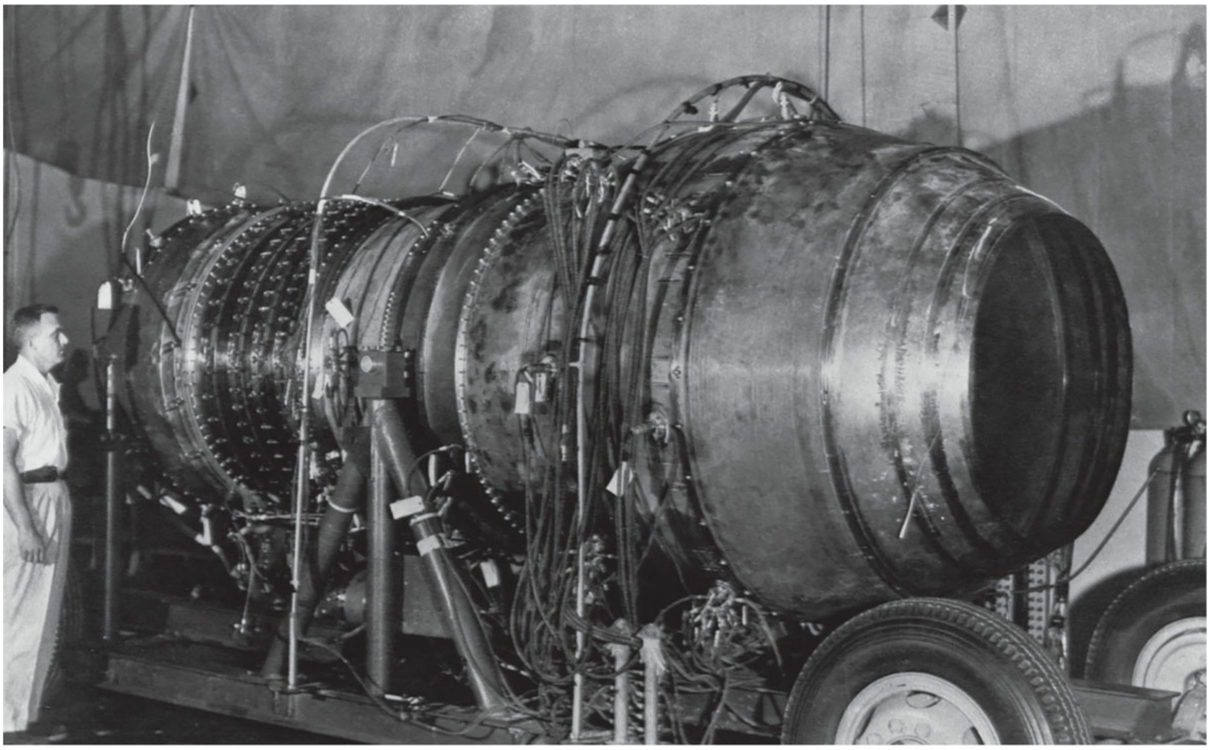
CL-400-12 Specifications:

Length--272 feet 0 inches
Wingspan--110 feet 0 inches
Wing Area--6,000 square feet
Height--50 feet 0 inches
Takeoff Gross Weight--255,530 pounds
Empty Weight--140,530 pounds
Fuel Load--115,000 pounds
Payload--1,500 pounds
Crew--2
Powerplant--4 x Pratt & Whitney 304-3

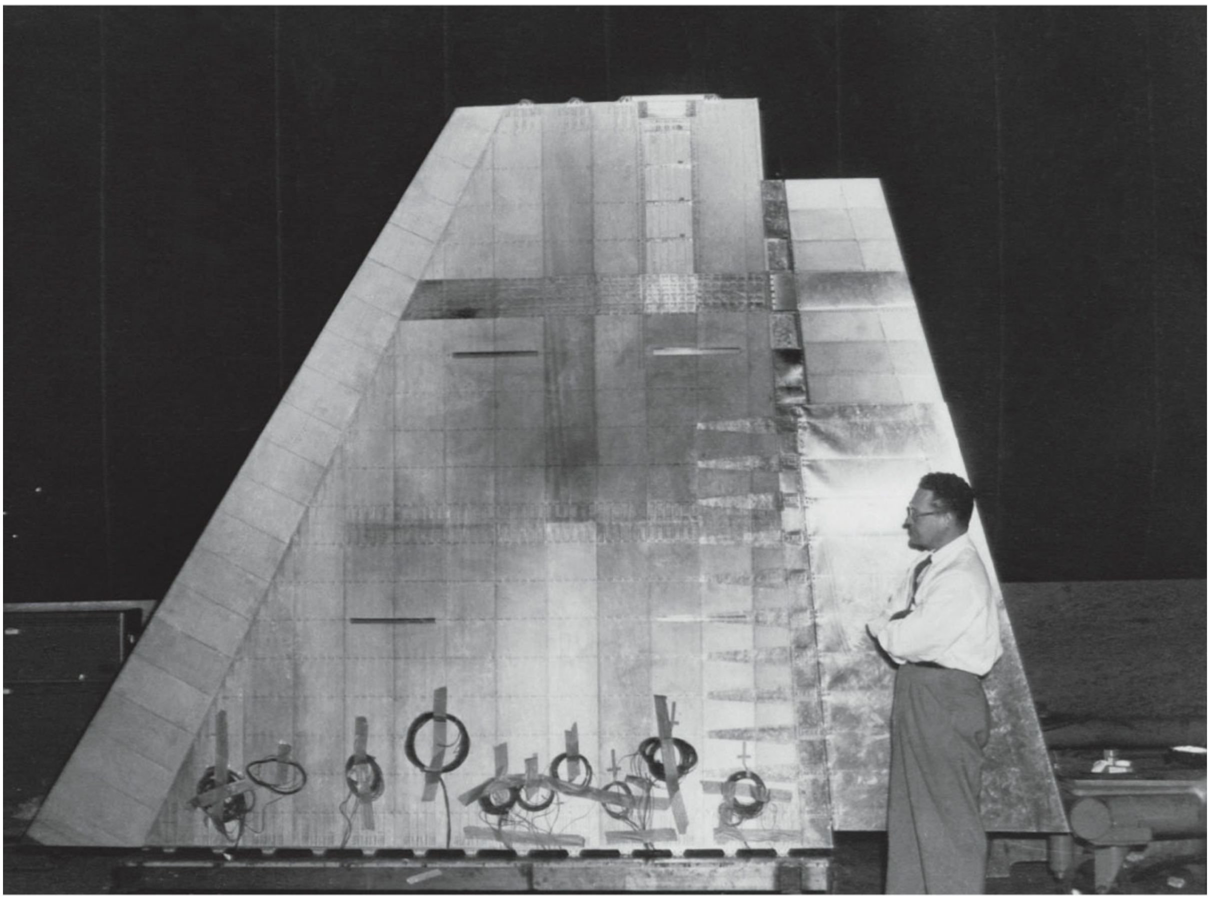
Drawing for the CL-400-12 configuration. (Lockheed Martin)



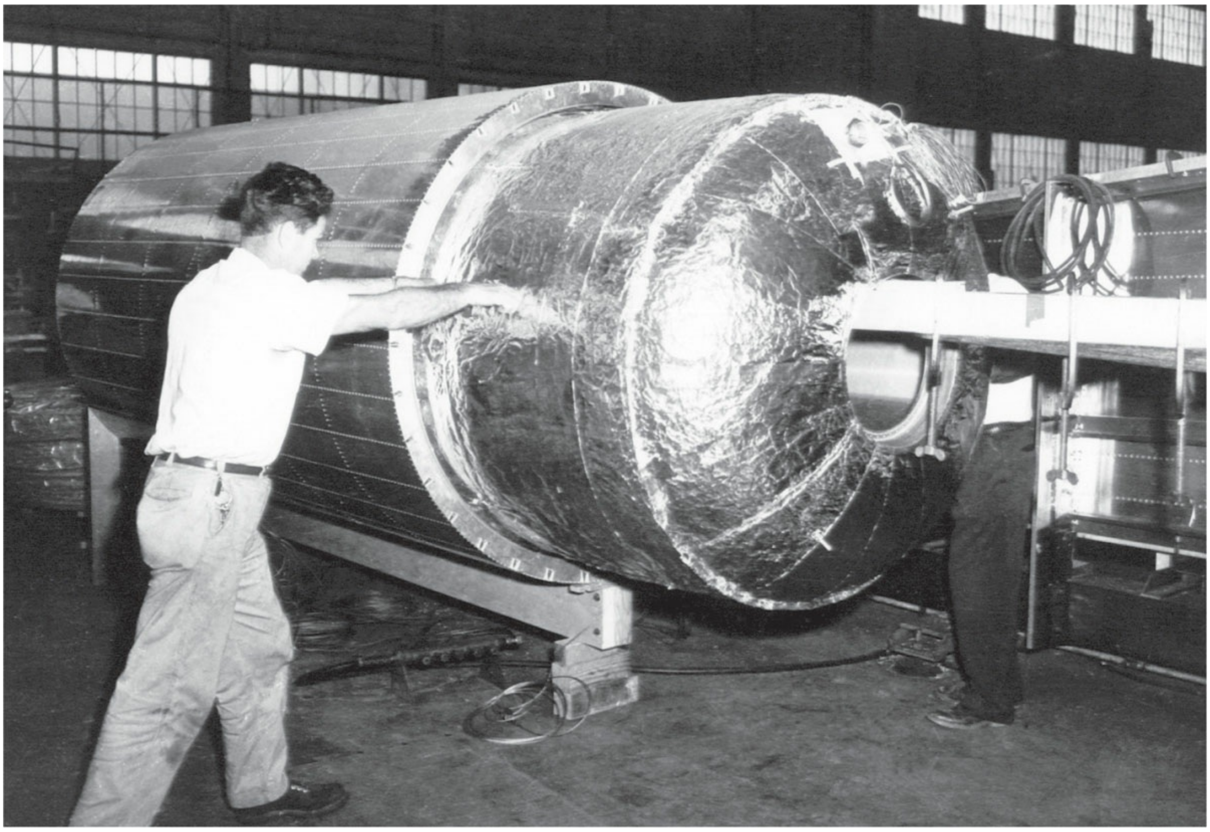
An illustration of the CL-400 Suntan refueling another CL-400. (Author's collection)



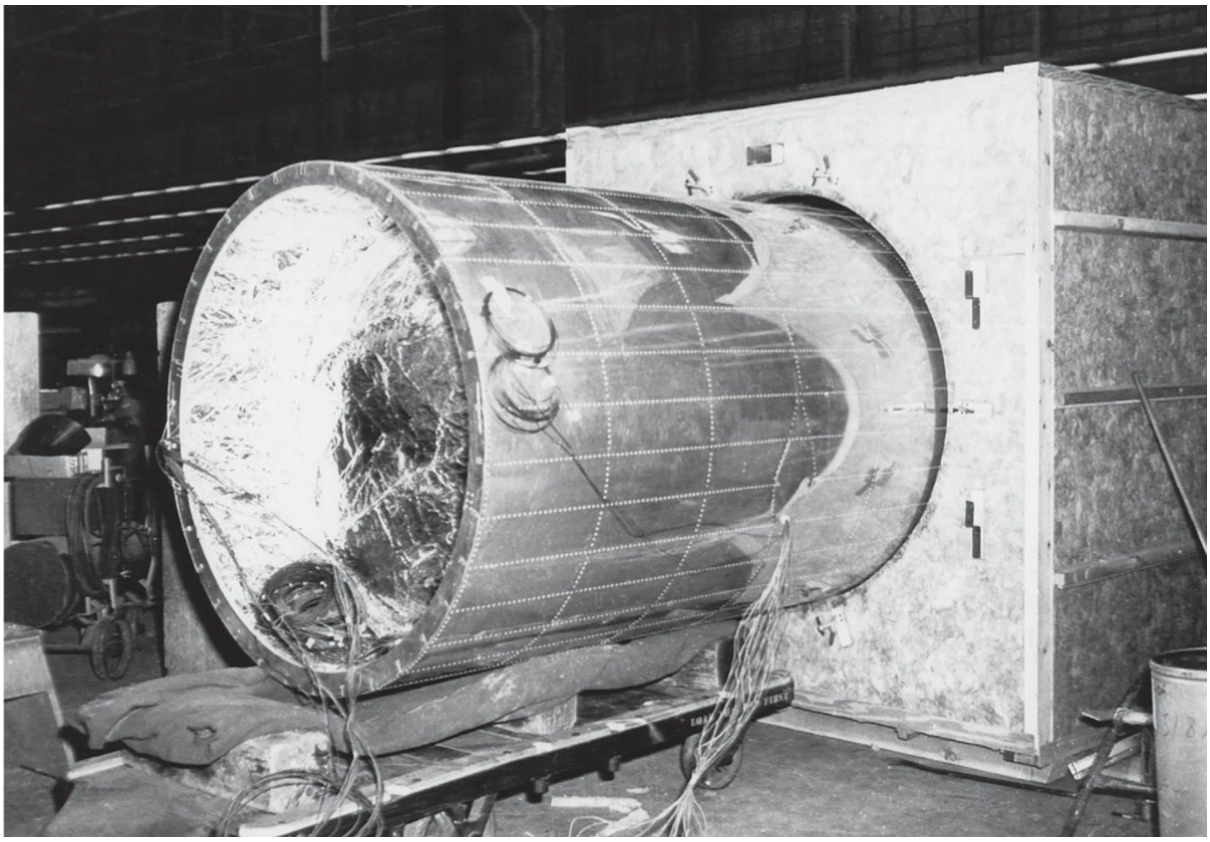
A Pratt & Whitney Model 304 liquid hydrogen-fueled jet engine. Several versions of this engine, each an improved version of previous engines, were built and tested at Pratt & Whitney's flight-test facility in West Palm, FL. (Author's collection)

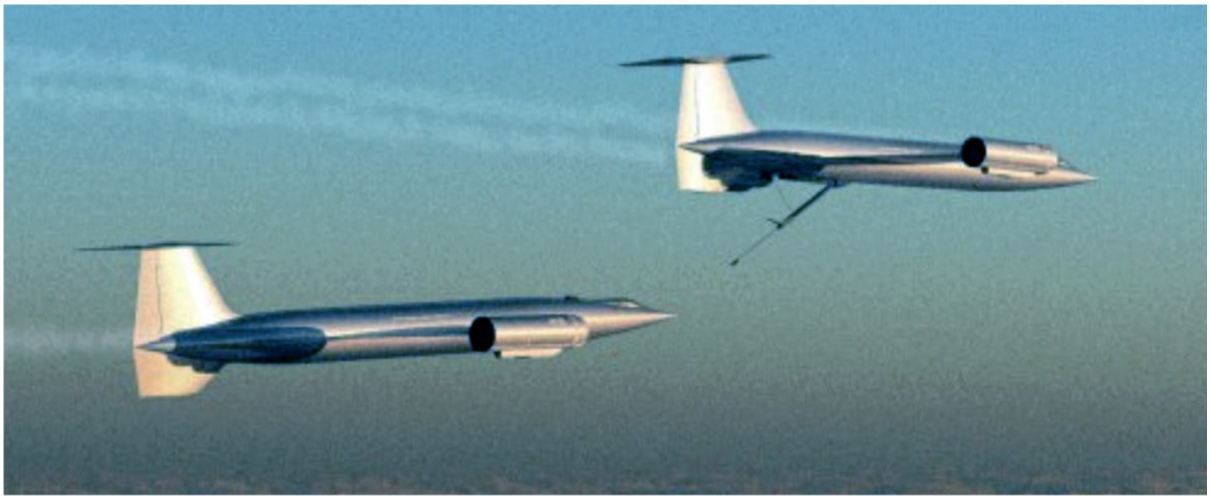


A one-third scale wing for the CL-400 and associated control surfaces was extensively instrumented to monitor and evaluate for vibration and structural integrity. (Author's collection)

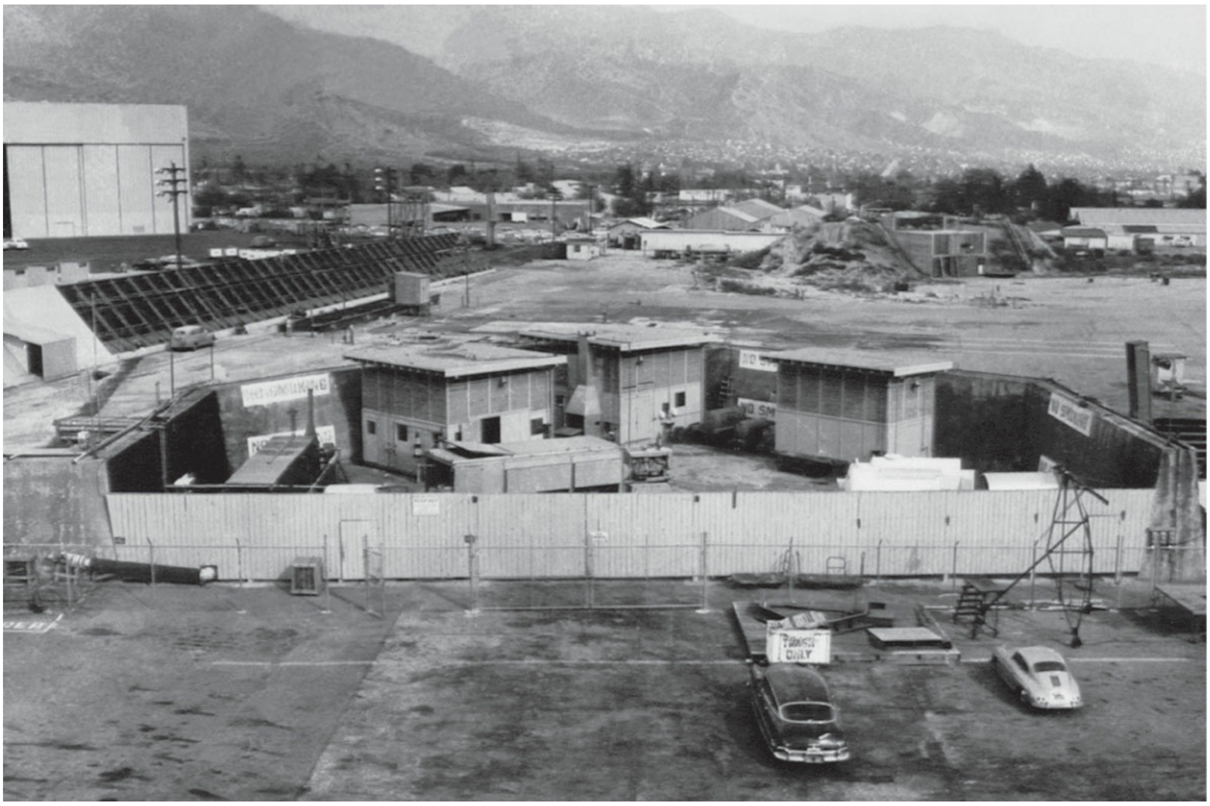


A heavily insulated liquid hydrogen tank test specimen being installed in a simulated CL-400 fuselage section. (Author's collection)

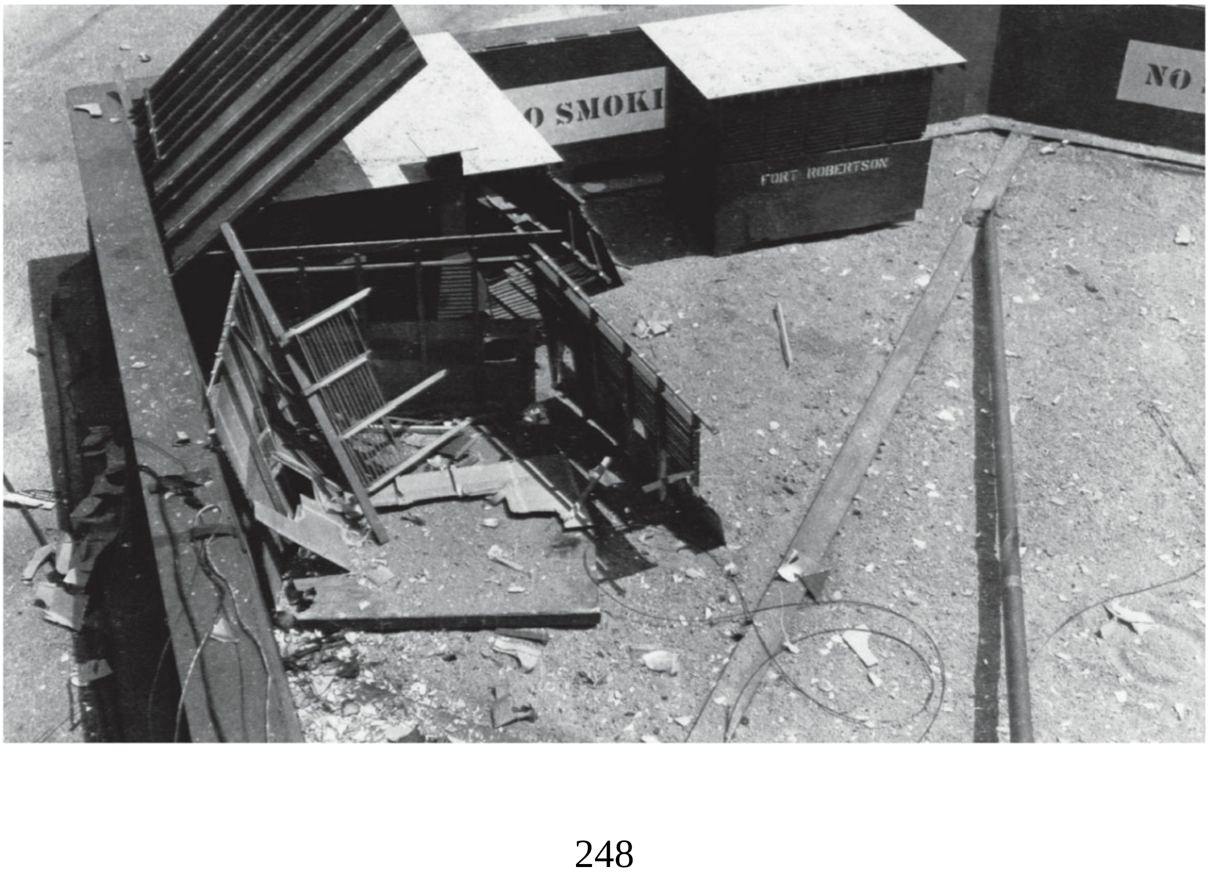




An illustration of two CL-400s in a simulated air-to-air refueling scenario. (Author's collection)



Fort Robertson outside of the original home of the Lockheed Skunk Works at the Hollywood Burbank Airport, formerly called the Bob Hope International Airport. (Author's collection)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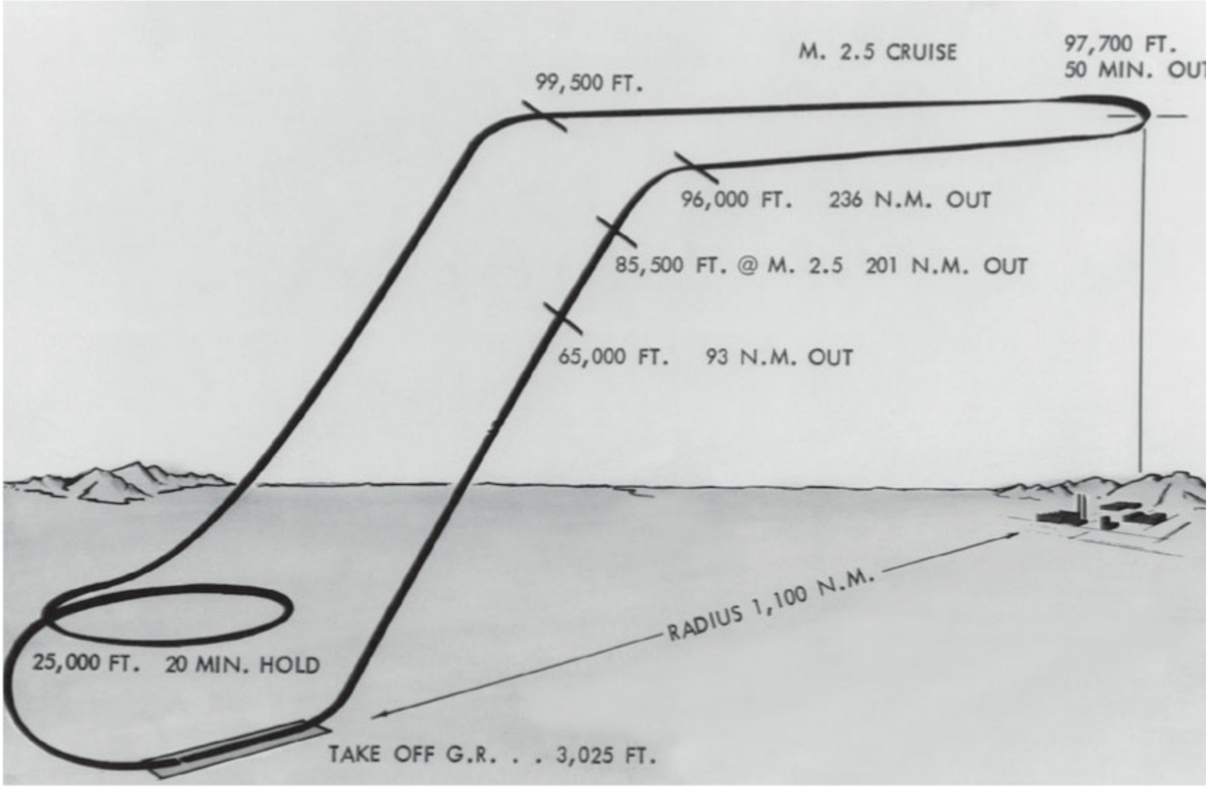
NO
FORT ROBERTSON

The result of an uncontained failure of one of the test insulated liquid hydrogen fuel tanks at Fort Robertson. (Author's collection)


M. 2.5 CRUISE
97,700 FT.
50 MIN. OU
99,500 FT.
96,000 FT. 236 N.M. OUT
85,500 FT. @ M. 2.5 201 N.M. OUT
65,000 FT. 93 N.M. OUT
RADIUS 1,100 N.M.
25,000 FT. 20 MIN. HOLD
TAKE OFF G.R. . . . 3,025 FT.

Flight profile of a possible mission that was conceived with the CL-400 in mind. (Author's collection)

A-12 OXCART

1962

PROGRAM: A-12 Oxcart

Name: Blackbird

Mission: Strategic reconnaissance

Length: 102ft 3in (31.16m)

Wing Span: 55ft 7in (16.94m)

Height: 18ft 6in (5.64m)

Max T.O. Weight: 117,000lb (53,000kg)

First Flight: 26 April 1962

Last Flight: 21 June 1968

Crew: 1; 2 in the TA-12 trainer

Number Built: 15

Power Plant: 2 x Pratt & Whitney J75; 1 x Pratt & Whitney J58 (JT11D-20)

Design Speed: Mach 3.24 (2,150mph; 3,460km/h)

Service Ceiling: >90,000ft (>27,430m)

Combat Radius: Unlimited with in-flight refueling

Cameras: Eastman Kodak Type II & Perkins Elmer Type I

Soon after the U-2's first flight during August 1955, Richard Bissell moved quickly to organize the research and undertake the development of follow-on systems, including what was to become the A-12. Bissell, various members of the Killian Committee, the board reviewing the proposal for aerial reconnaissance, and Johnson had concluded that the U-2 would have a period of invulnerability lasting no more than two years from the beginning of the Russian espionage effort (codenamed Operation Overflight).

One of the first surprises of the U-2 overflight program was the ease with which Soviet ground-based radar systems found and tracked the aircraft before, during and after it penetrated Russian airspace. As a result, considerable effort was placed on reducing the aircraft's radar cross section (RCS), but with only limited results. The aircraft's high operating altitude remained its best defense.

Attention in the CIA, under the auspices of John Parangosky, now focused on the possibility of building a vehicle that could fly at extremely high speeds and extraordinarily high altitudes while incorporating the most advanced radar-attenuating capabilities then available. During the fall of 1957, Lockheed Aircraft Corporation and the Convair division of General Dynamics were invited to respond to a highly classified general operational requirement calling for a high-speed, high-altitude reconnaissance aircraft specifically to replace the increasingly vulnerable U-2. Security constraints prevented a formal contract or overt government funding, but it was understood that both companies, if the project was funded, would be compensated for the study expense when the time proved appropriate.

Johnson spent virtually every available minute working on the advanced aircraft program – which he referred to initially as the "U-3." As early as 21 April 1958, he noted in the first entry for what was to become his A-12 log/diary, "I drew up the first Archangel [the unclassified program name Kelly Johnson gave to the A-12 Oxcart] proposal for a Mach 3 cruise airplane having a 4,000 nautical mile range at 90,000 to 95,000 feet."

Eventually, Johnson concluded that Lockheed's only chance of success in building a Mach 3 cruise-capable aircraft would be to have a 41,000lb empty weight; a 100,000lb gross weight; 59,000lb of fuel; 2,000lb of fuel reserve; and 14,000lb of thrust. The radius of action would be 2,000 nautical miles using 43,000lb of available fuel.

Ben Rich, who eventually would play a key role in the A-12's development said, "We calculated everything with a slide rule and a Friden calculator."

This was a difficult and laborious process, as computer technology was rudimentary at best, and capabilities were extremely limited. Complicating things was the extraordinary security blanket that had been thrown over the project. The A-12 inhabited the black world for many years. The CIA knew about development of the A-12 as did a few people in the Air Force, a few Congressmen, and of course, President Eisenhower. Security rivaled the Manhattan Project. Those on the project never used the name Lockheed, no drawings were stamped, and (later) parts were sent to C&J Engineering (Kelly's initials) and Kelly had things mailed to post office boxes all over the city. Lockheed maintained perimeter security and even swept out their own offices.

During this period Lockheed studied models from A-3 to A-12. Gradually it became evident that Lockheed could not obtain radar invisibility and all the other conditions desired for the airplane. In April 1959, Kelly proposed the concept of a single base operation with air-to-air refueling, operating out of Muroc. The result was the A-11: an airplane for which no compromises for radar were made but which had very good performance and was a straightforward twin J58 Mach 3.2 airplane.

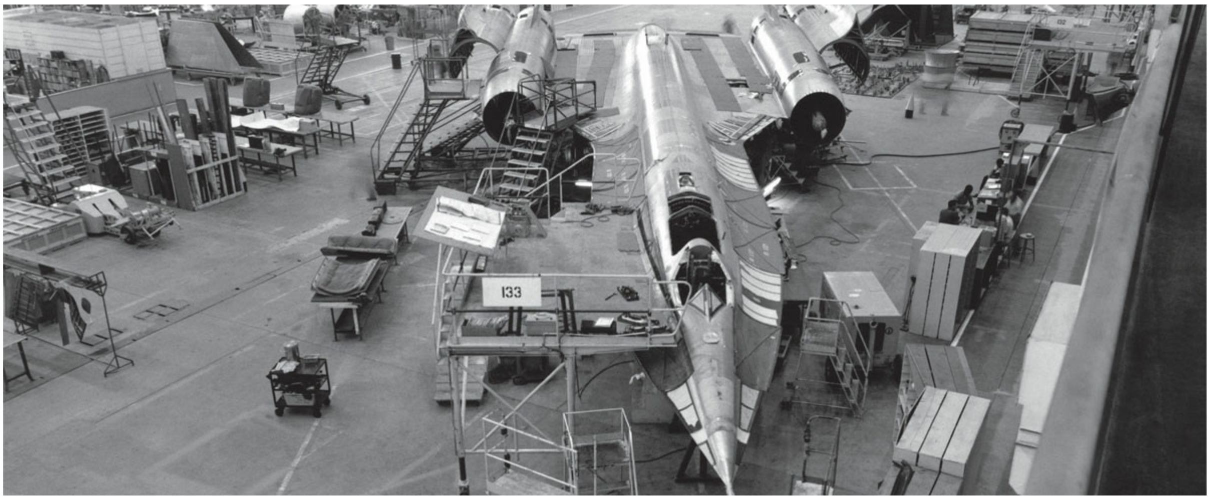
Kelly made some kind of impression with the radar people, because the ground rules changed shortly after this and it was agreed that the A-11 would make such a strong target that it might be taken for a bomber.

On 3 July, when Kelly thought that Lockheed were ruled out, the Killian Committee extended the program and agreed to accept lower cruising altitudes which Lockheed could obtain with a version of the A-11 adapted in shape and treatment to reduce the cross section. The A-12 was proposed, with the use of chines on the fuselage and serrations on the leading-edge, incorporating radar treatment which would reduce the radar cross section by a significant factor. With this new configuration, the A-12 grew to weigh about 110,000–115,000lb.

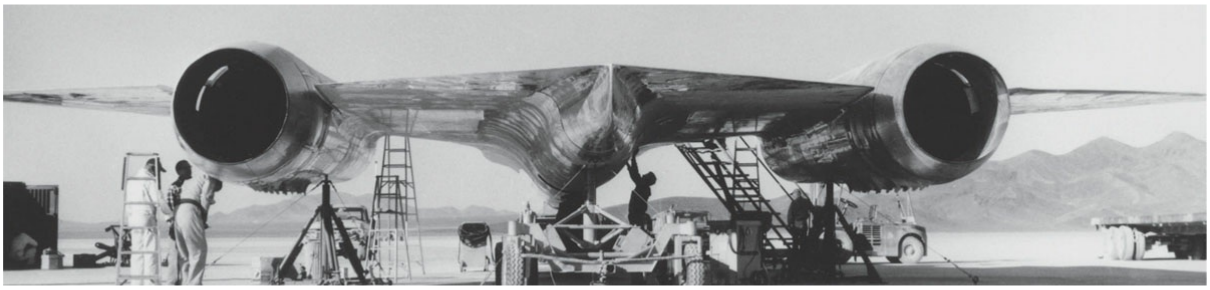
Thus, the definitive A-12 configuration was the last of 12 major configuration studies that had started with the original Archangel calculations of nearly a year earlier. Within each "A" study series, a large number of perturbations had been explored, most of which were assigned sub-designators such as A-6-9, etc.

On 31 August 1959, Johnson noted in the log, "Started immediate action in Building 82A to build full-scale mockup and 1/8 scale mockup, an elevation post, and engineering reorganization and expansion, and plans for a complete rearrangement of offices and shop." Johnson noted, "I consider this to be the first day on our new project, with a flight date set 20 months from today. The original 18-month program will be delayed to allow Pratt & Whitney to make a by-pass version of the J58 engine." On 8 February 1960, the first production contract was let on Oxcart.

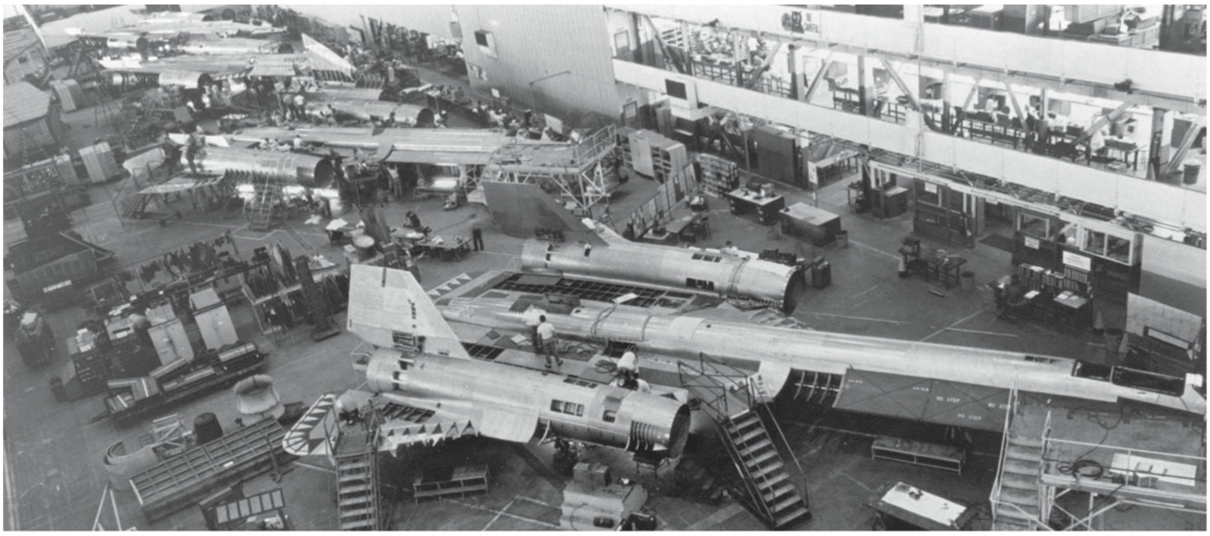
The author, Jim Goodall, in the Minnesota Air Guard Museum's A-12, 60-6931/128. (Author's collection)



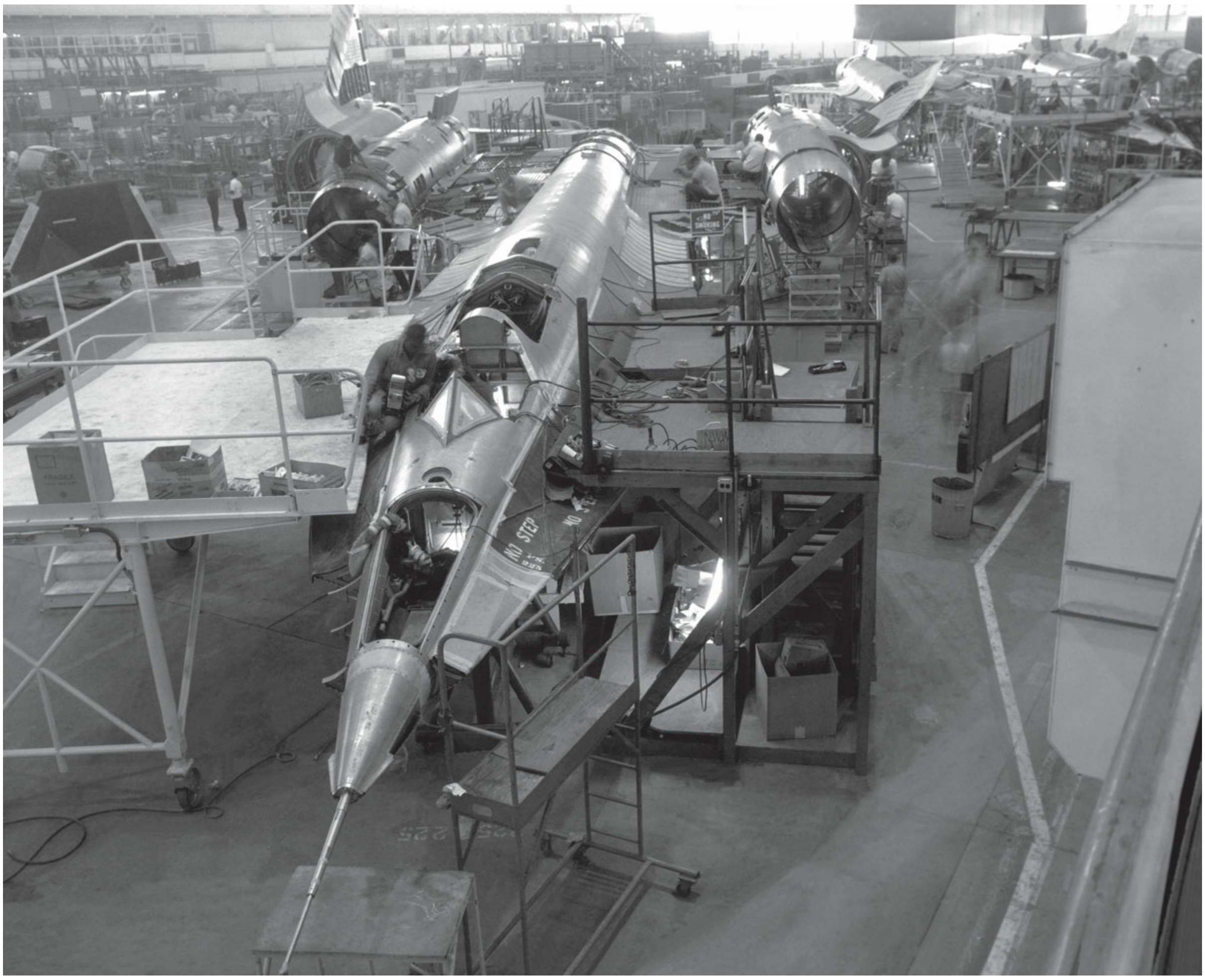
The last A-12 built, A-12 60-6939/133, on the production line at the Lockheed Skunk Works in late 1963. (Author's collection)



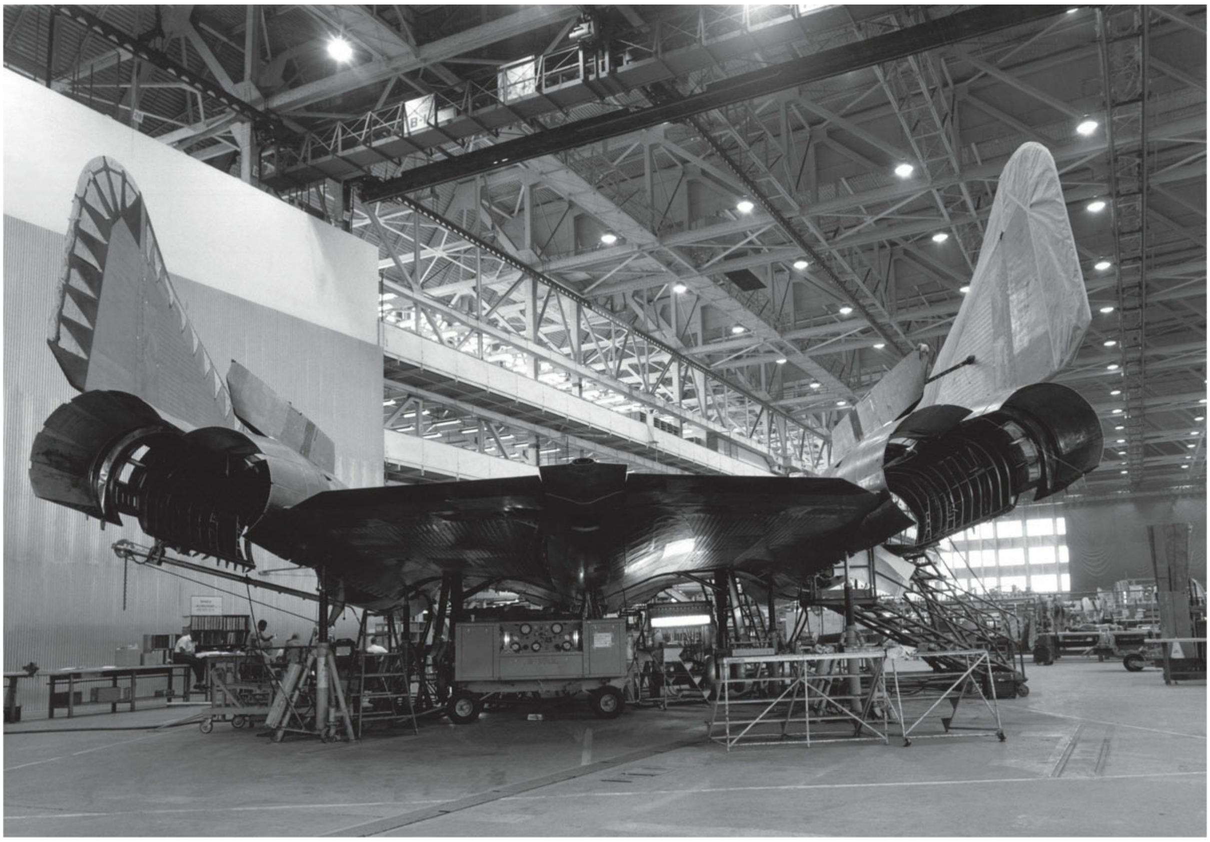
A rear view of a full-scale model of an A-12 readied for test on the RCS pole on the west side of Groom Dry Lake prior to being raised up to a testing height. (Author's collection)



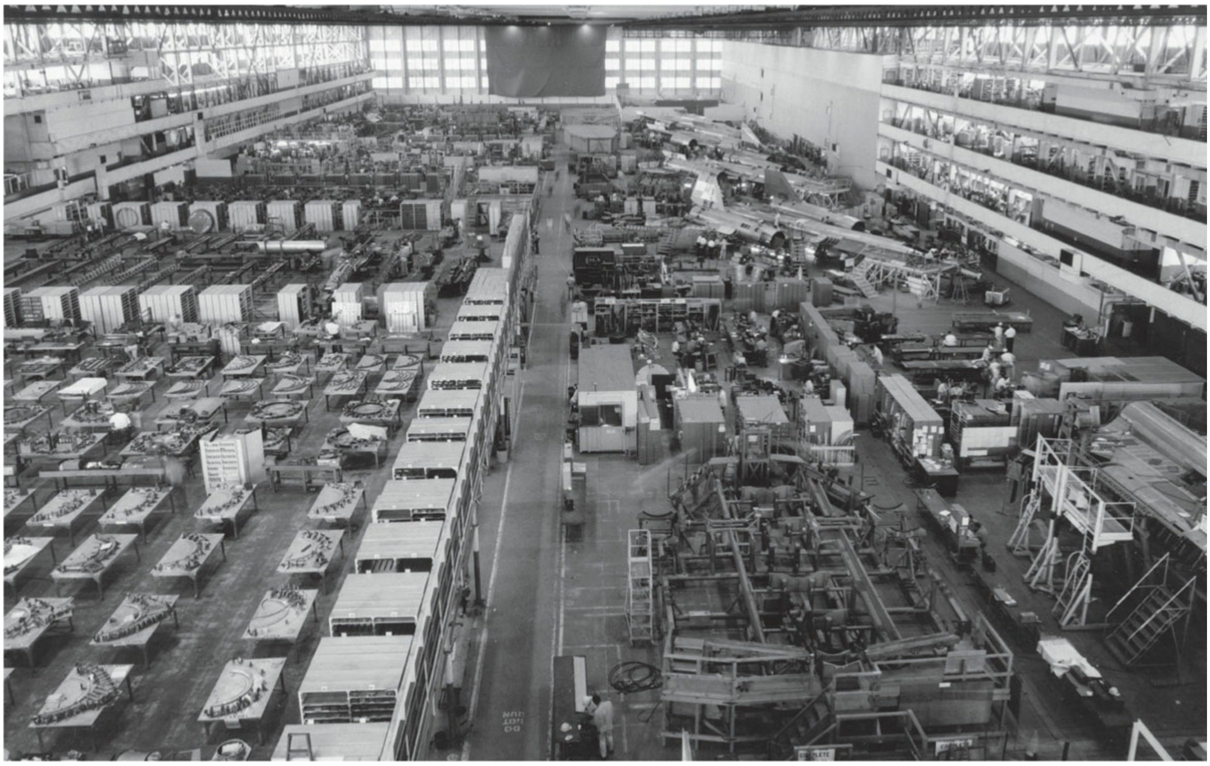
A production lineup of A-12s under construction with A-12 60-6926/123 closest to the camera; followed by the Titanium Goose, aka the TA-12, 60-6927/124; and A-12 60-6928/125 next. (Author's collection)



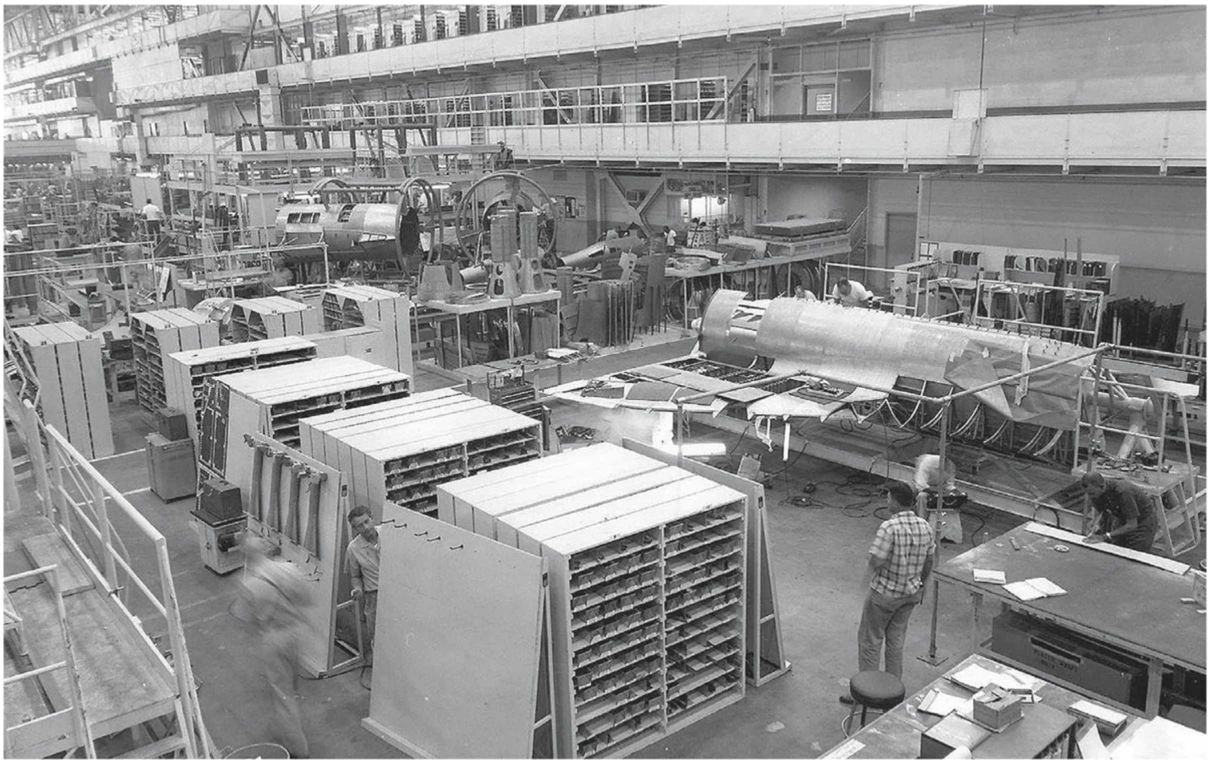
The beginning of the buildup of the eight production A-12, 60-6931/128 that eventually became the star of the Minnesota Air Guard Museum before being moved to the Headquarters of the CIA in McLean, VA. (Author's collection)



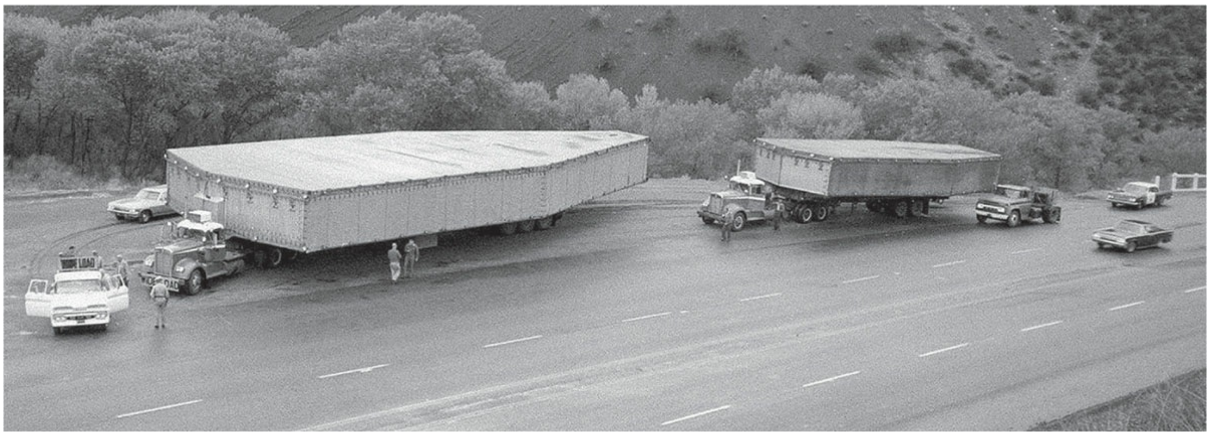
The A-12 Blackbird production line at the Lockheed Skunk Works Burbank production facility. The image, taken in the summer of 1963, shows the rear view of the second A-12 built, A-12 60-6925/122. The second A-12 can be seen at the USS Intrepid Sea, Air & Space Museum on the New York City waterfront. (Author's collection)



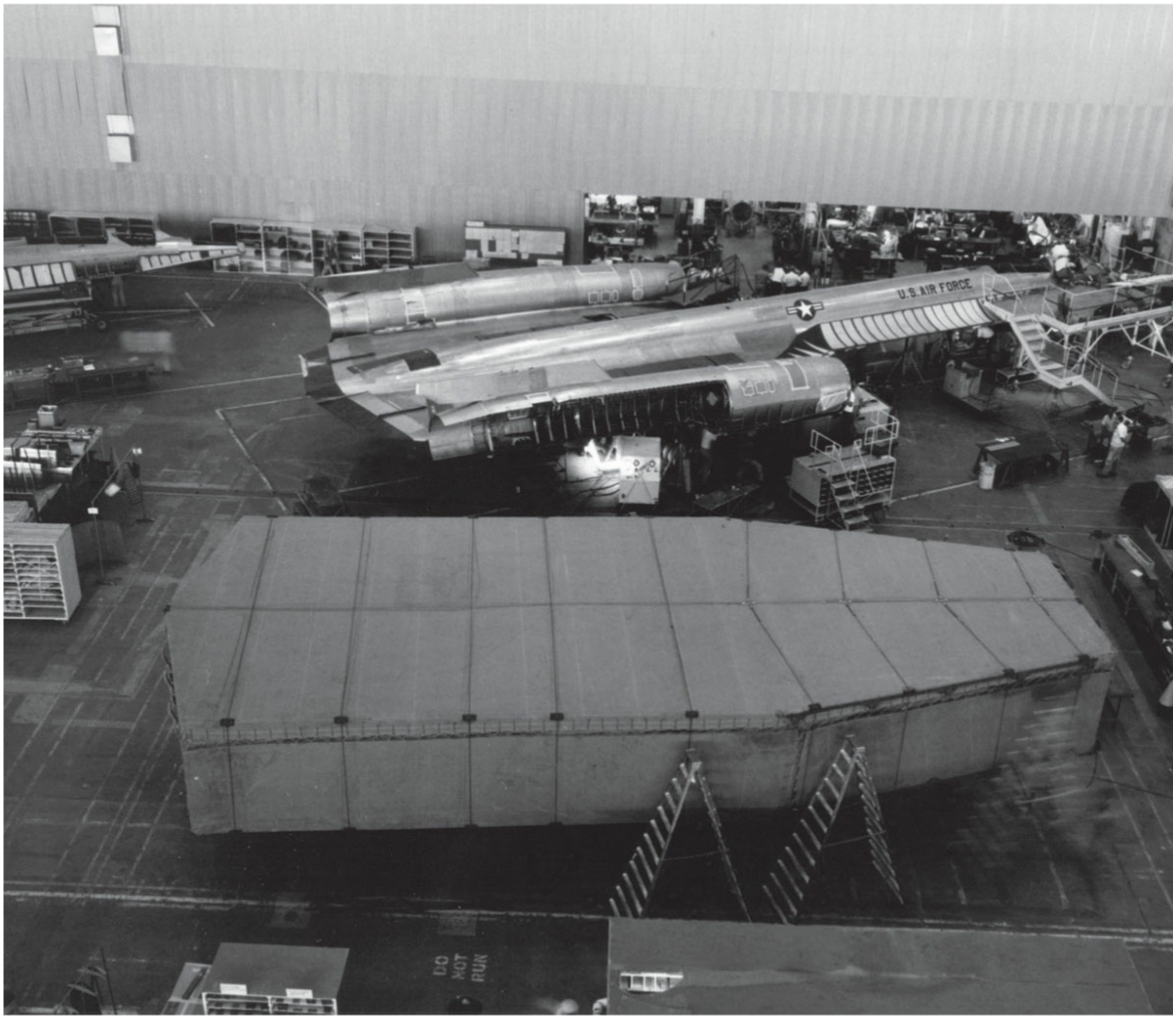
A long look down the A-12 production facility at the Lockheed production line with the A-12 transporting trailer in the foreground. (Author's collection)



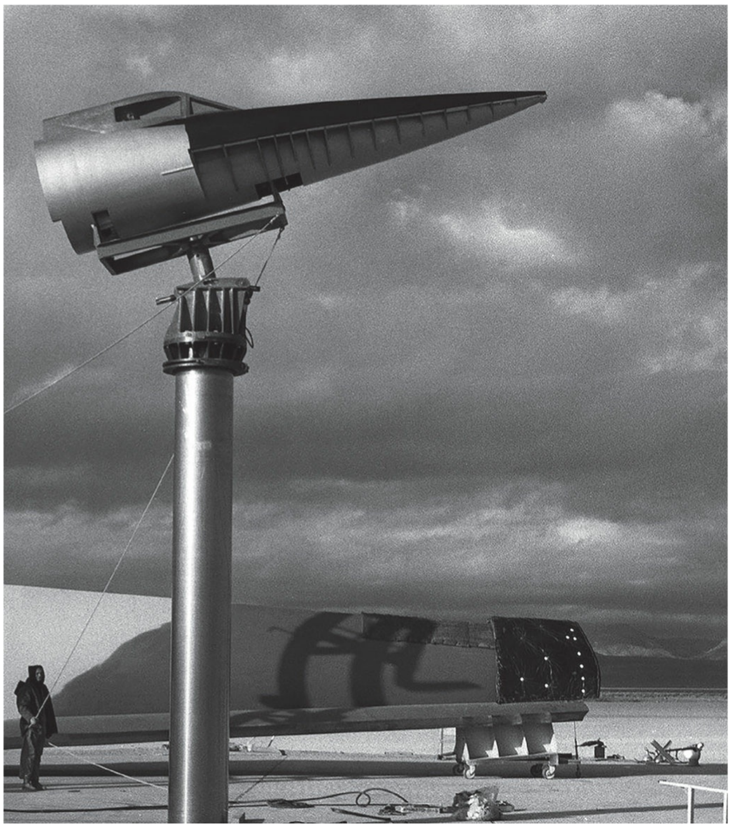
Outer wing panel assembly area on the south side of the Lockheed Skunk Works production and assembly facility in Building 309/310. (Author's collection)



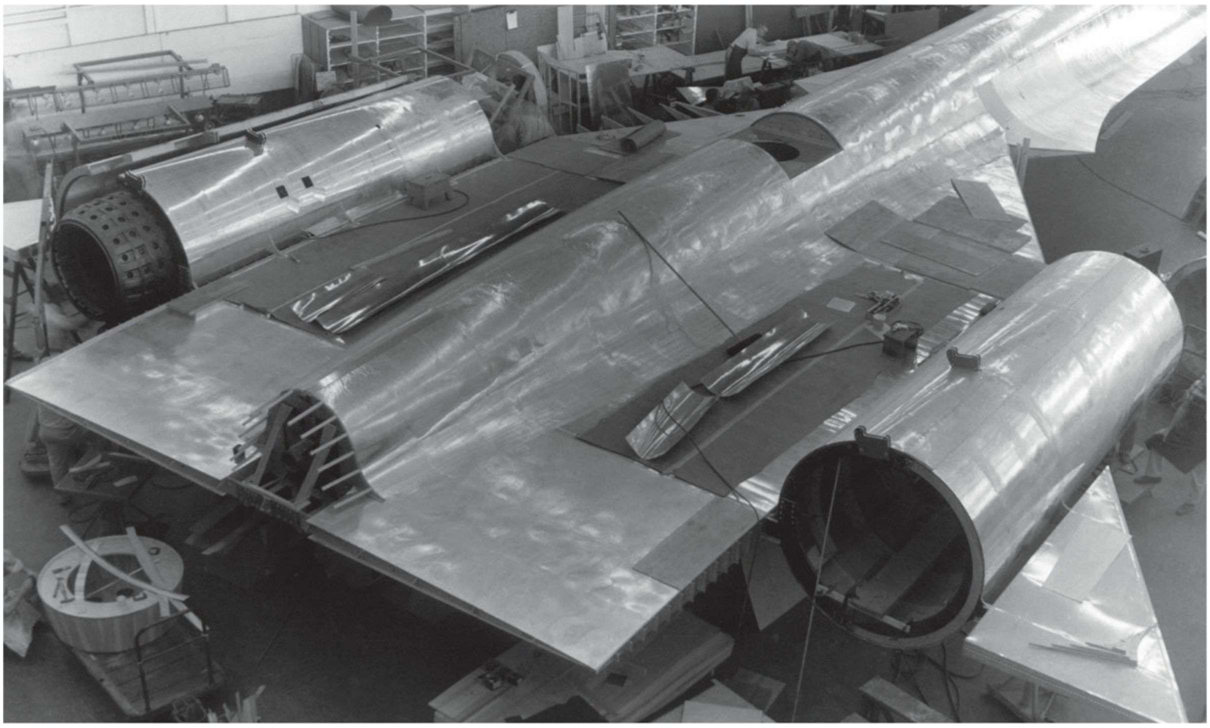
A rest stop on the way to Area 51 via the road to Mercury, NV. A funny story told how the trailers carrying the fuselage of the A-12, in making a tight turn, accidentally hit a farmer's pickup truck. The CIA officials on the scene paid the farmer the full new replacement cost of his beat-up pickup truck to keep him quiet, and he was able to keep the truck, but they told him if he said anything of what he saw, he would be in for a very rude awakening. (Author's collection)


U.S. AIR FORCE
DO NOT RUN

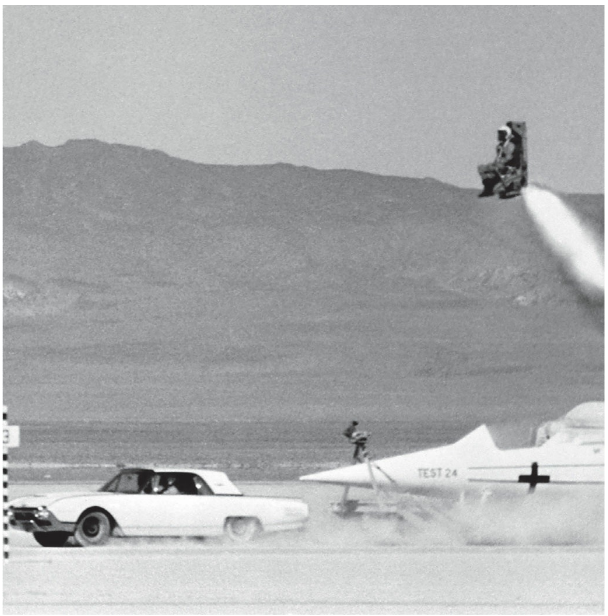
Almost ready for the road, the very first A-12, 60-6924/121, all packed up and ready to go. (Author's collection)



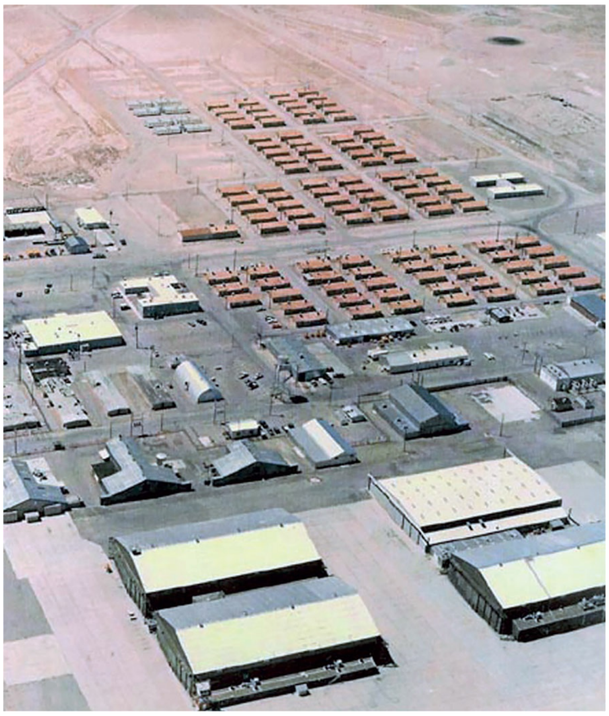
Testing the nose of the A-12 at the Area 51 RCS Range. By performing this test, Lockheed could evaluate the RCS of just the nose section of the A-12. (Author's collection)



With the requirement for a lower RCS, the A-12 RCS model was reworked to include the all-too-familiar chines that are one of the key visible aspects of the Lockheed Blackbirds. (Author's collection)



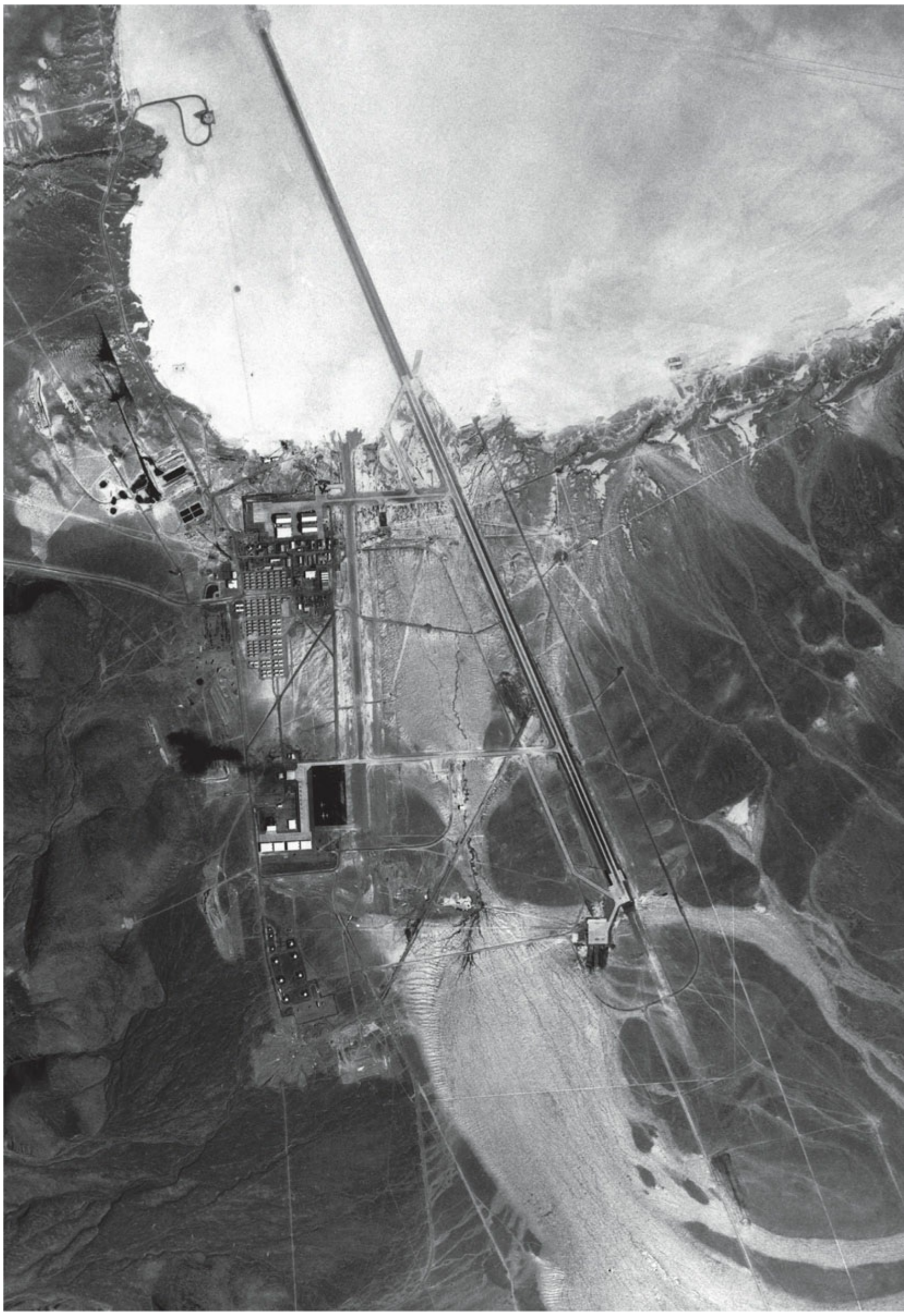
There had to be a way to test the ejection seat from an A-12 forward cockpit mockup to see if and how the seat would work in a real-life ejection at takeoff or landing speeds. At first they rented a 1960 Pontiac Bonneville from Hertz, but blew the transmission at 125mph; the next rental was a Ford T-Bird as seen in this photo. (Author's collection)



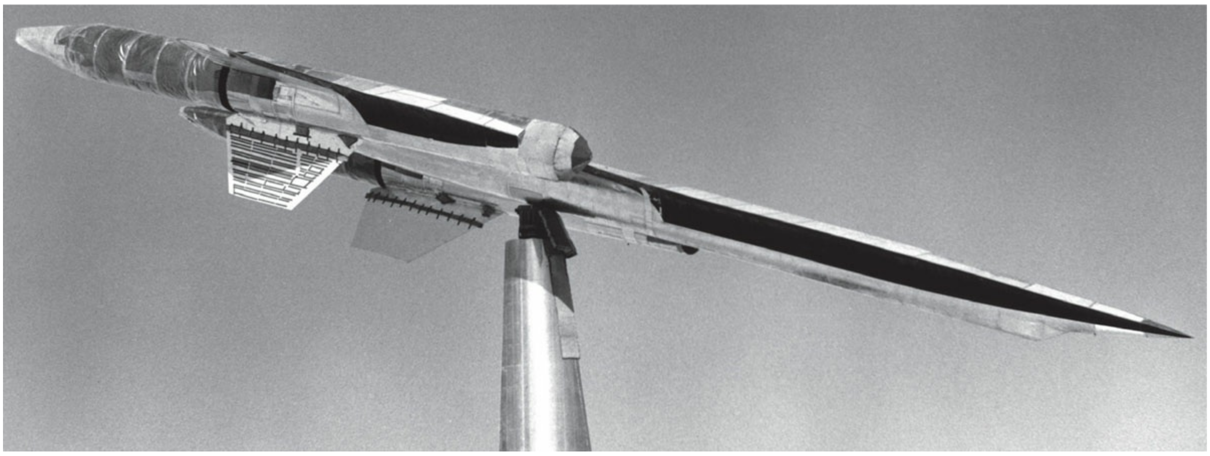
Area 51 photographed in 1963 looking to the south before the A-12 hangars were built at its sound end. (Author's collection)

GROOM DRY LAKE
DREAMLAND
AREA 51
TEST FACILITY

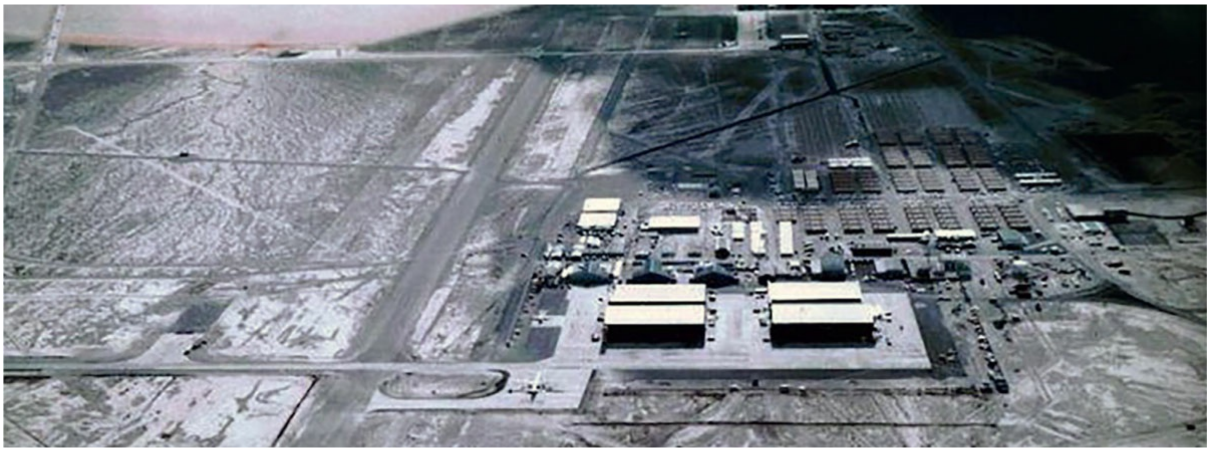
Area 51 patch designed by the author and first published in the March 1994 issue of Popular Science. (James C. Goodall)



Area 51 as seen from a USGS satellite in 1968 showing some of the important hangars and similar buildings that were used early in the development and flight-testing of the Blackbirds. (USGS)

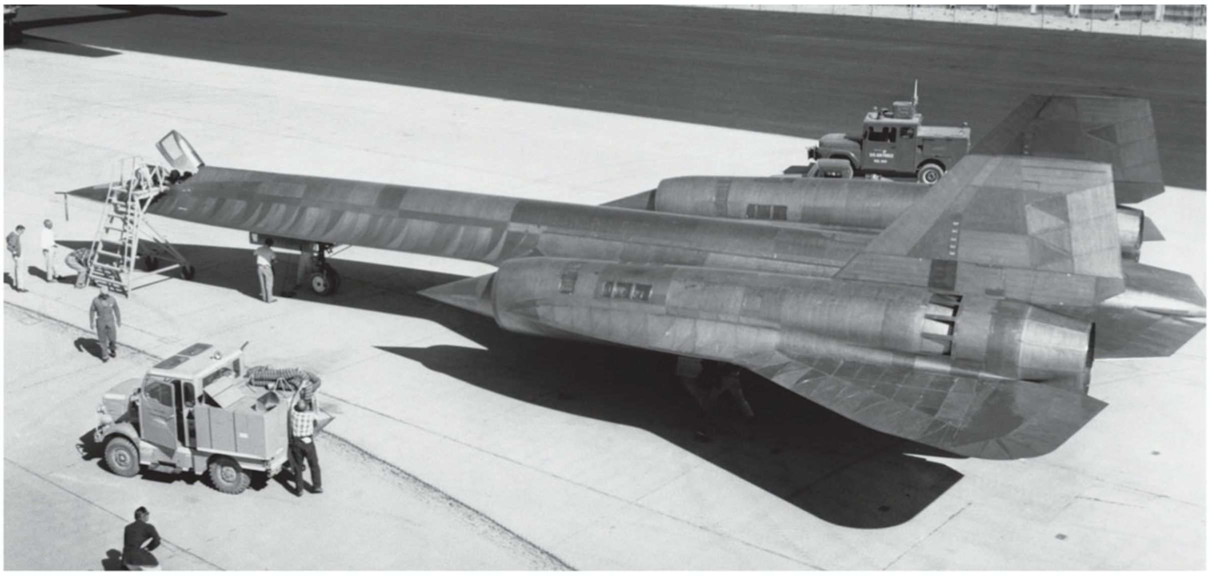


A side view of the full-scale A-12 RCS model with exhaust plumes, to evaluate the effect of the plumes on the RCS of the A-12 mockup. (Author's collection)

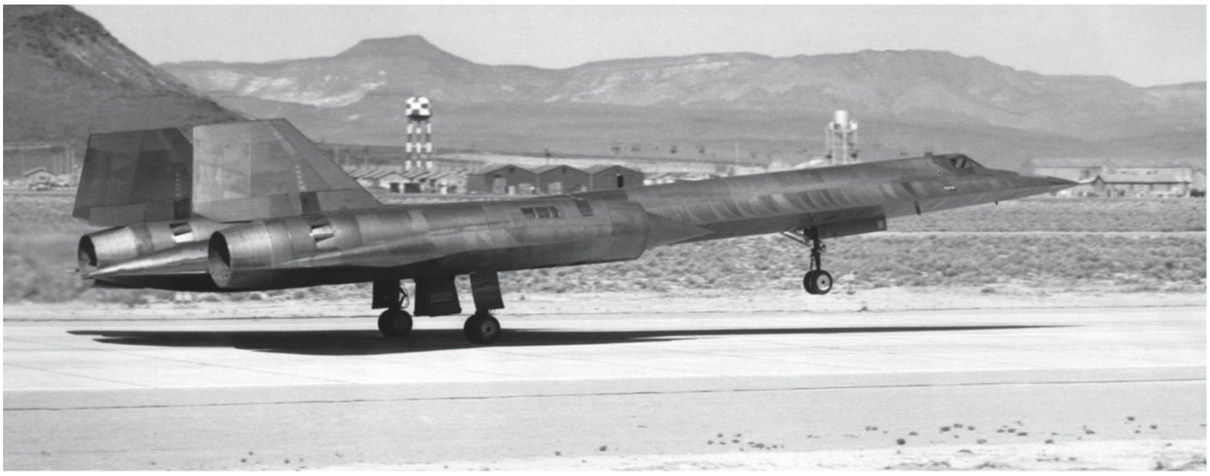


Another view of Area 51 taken in 1964 looking to A-12 hangars at the south end, also called "Baja." (Author's collection)

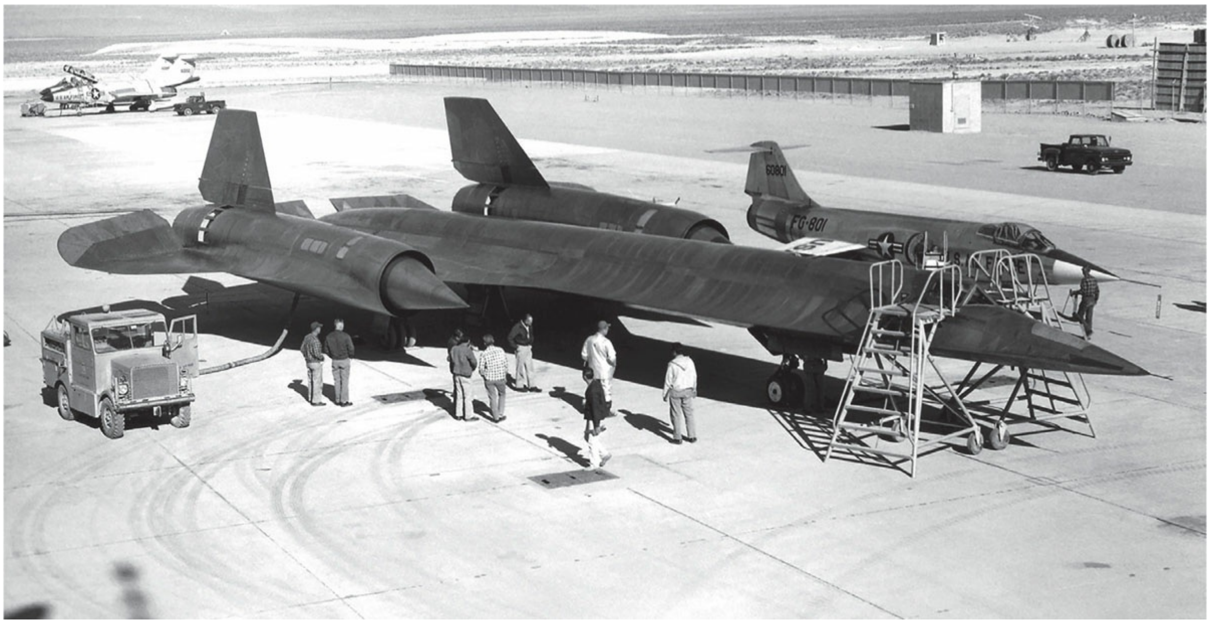
Hughes designed and built a 75ft-diameter SPS-13 RCS antenna on the south end of Groom Lake. It was used to validate the RCS of any aircraft or cruise missile that flew within its range. (Author's collection)



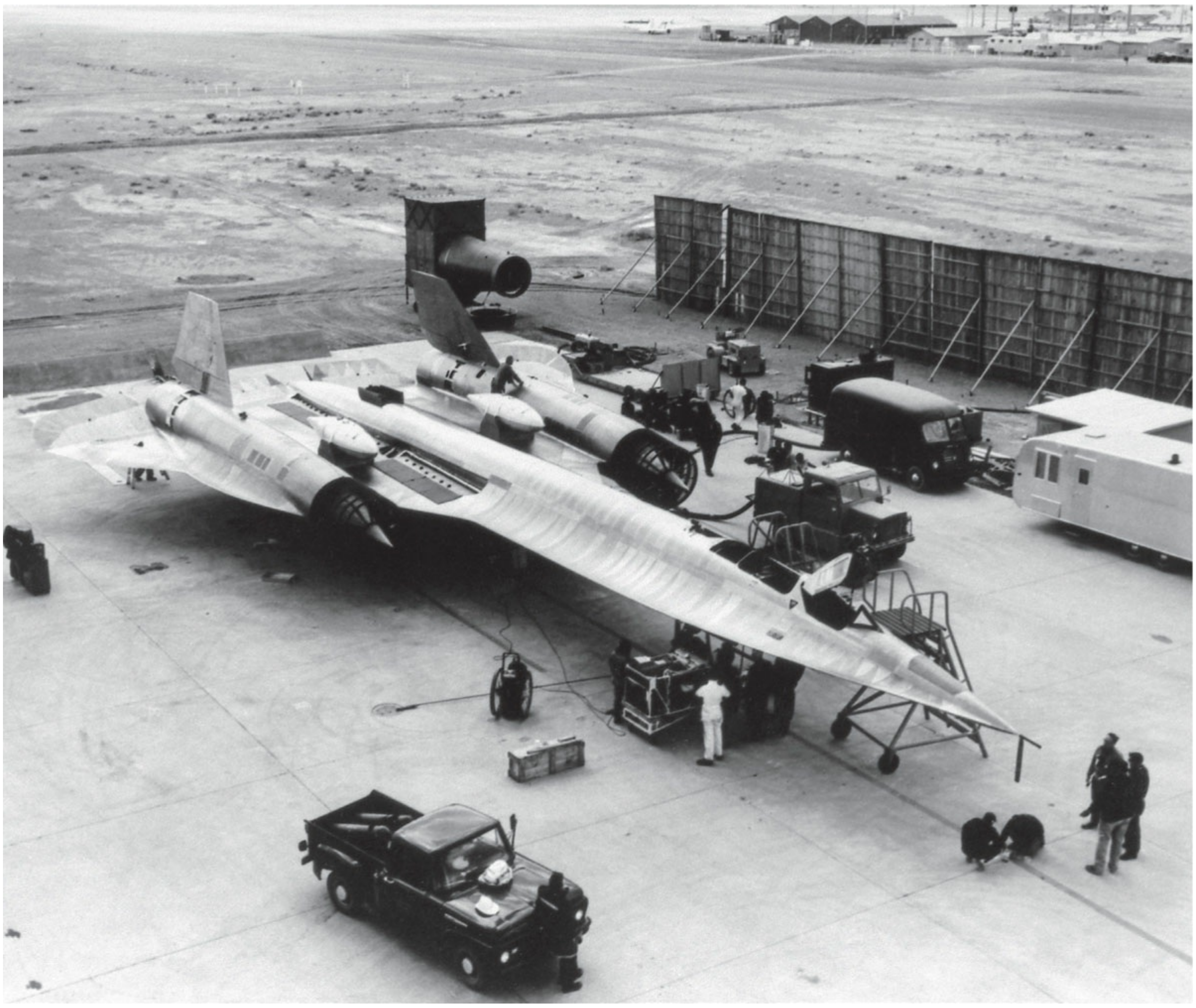
One of the prettiest look-down shots of the all-natural metal A-12 60-6924/121 on the ramp at Area 51 prior to its first flight on 26 April 1962. (Lockheed Martin)



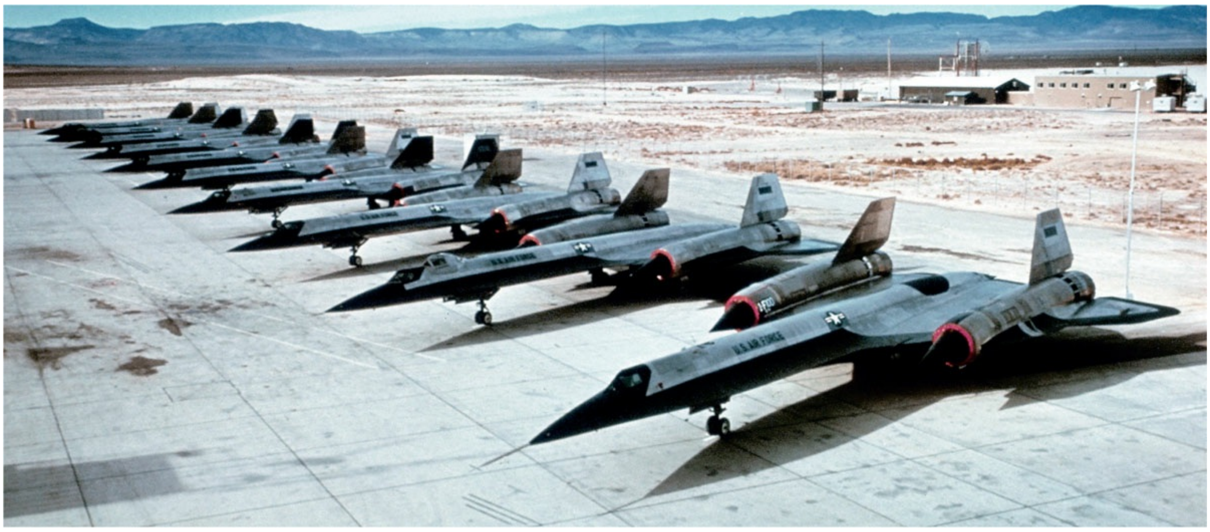
A beautiful shot of the very first landing of an A-12 at Area 51. During early flight-testing, all the A-12s at the test site were powered by the Pratt & Whitney J75. (Lockheed Martin)



The very first "non-black" Blackbird, A-12 60-6924/121, photographed as it was being prepped for its first flight on 26 April 1962. It was piloted by Lockheed test pilot Lou Schalk. (Lockheed Martin)



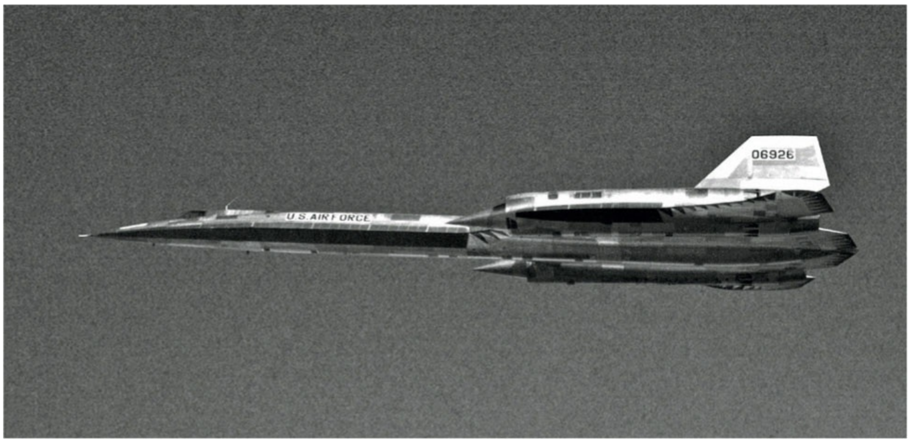
Looking down on the first A-12 during one of its earliest engine runs. The very first time that the A-12 was filled with fuel, it leaked like a sieve. The solution was to take two surplus F-84 underwing fuel tanks, build a cradle for them and use them for the fuel to run the engines prior to the leaking issues being corrected. (Author's collection)



The lineup of ten of Lockheed's famed Blackbirds on the ramp of Area 51 on 24 January 1964. In this photo are eight A-12s and two YF-12As at the far end. (Lockheed Martin)

FIRST AIRCRAFT WITH
100 HOURS
SN 123
APRIL 3RD, 1963

With Jim Eastham in the center, the crew of A-12 60-6926/123 sits for a group photo on the day the third A-12 reached 100 hours of flight time – 3 April 1963. (Lockheed Martin)



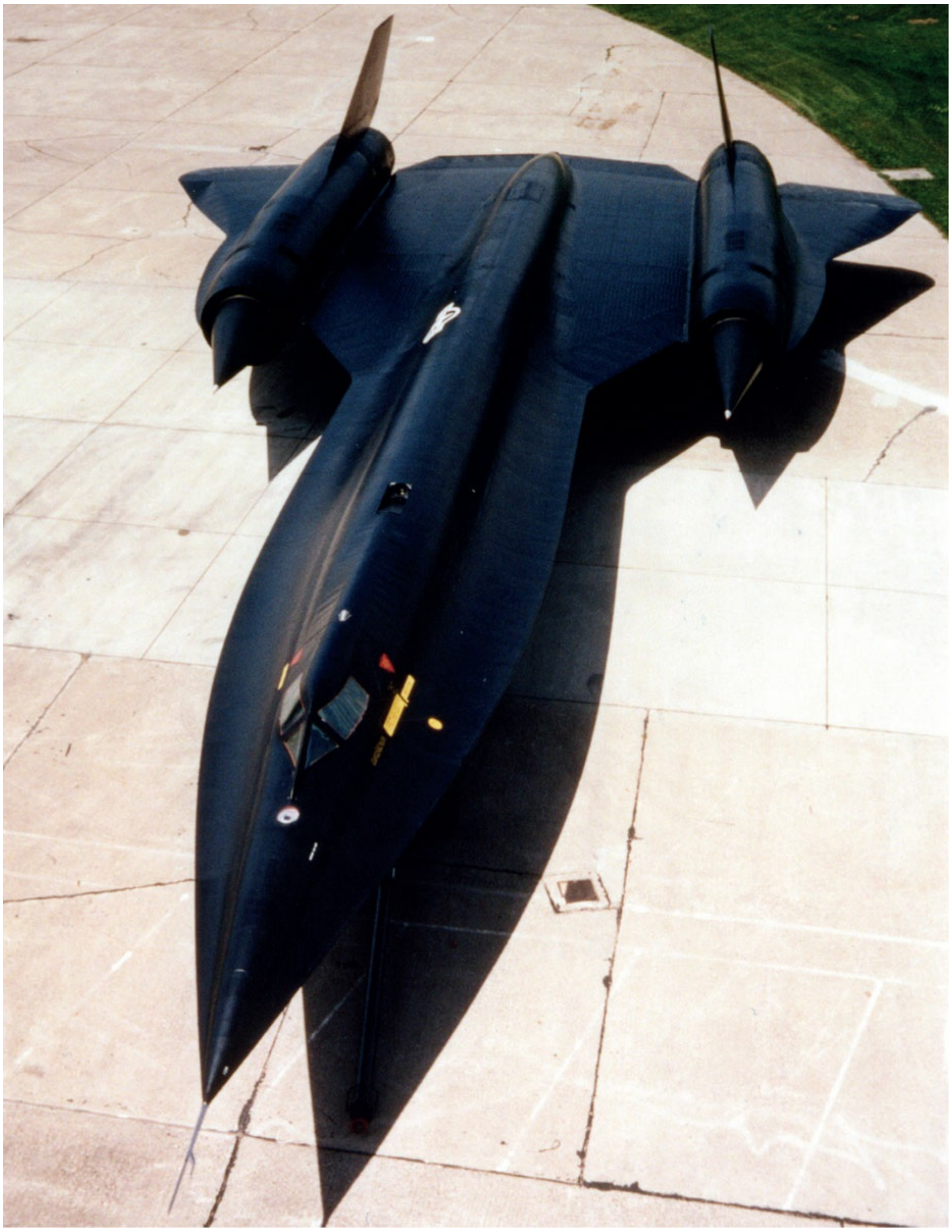
The third A-12, 60-6926/123, as viewed during this air-to-air photo session. The first flight of A-12 123 took place on 9 October 1962; it was flown by Lockheed chief test pilot Lou Schalk. Before its loss, A-12 60-6926/123 had a total of 79 flights and 135.2 hours of flight time. (Author's collection)

U.S. AIR FORCE
06926

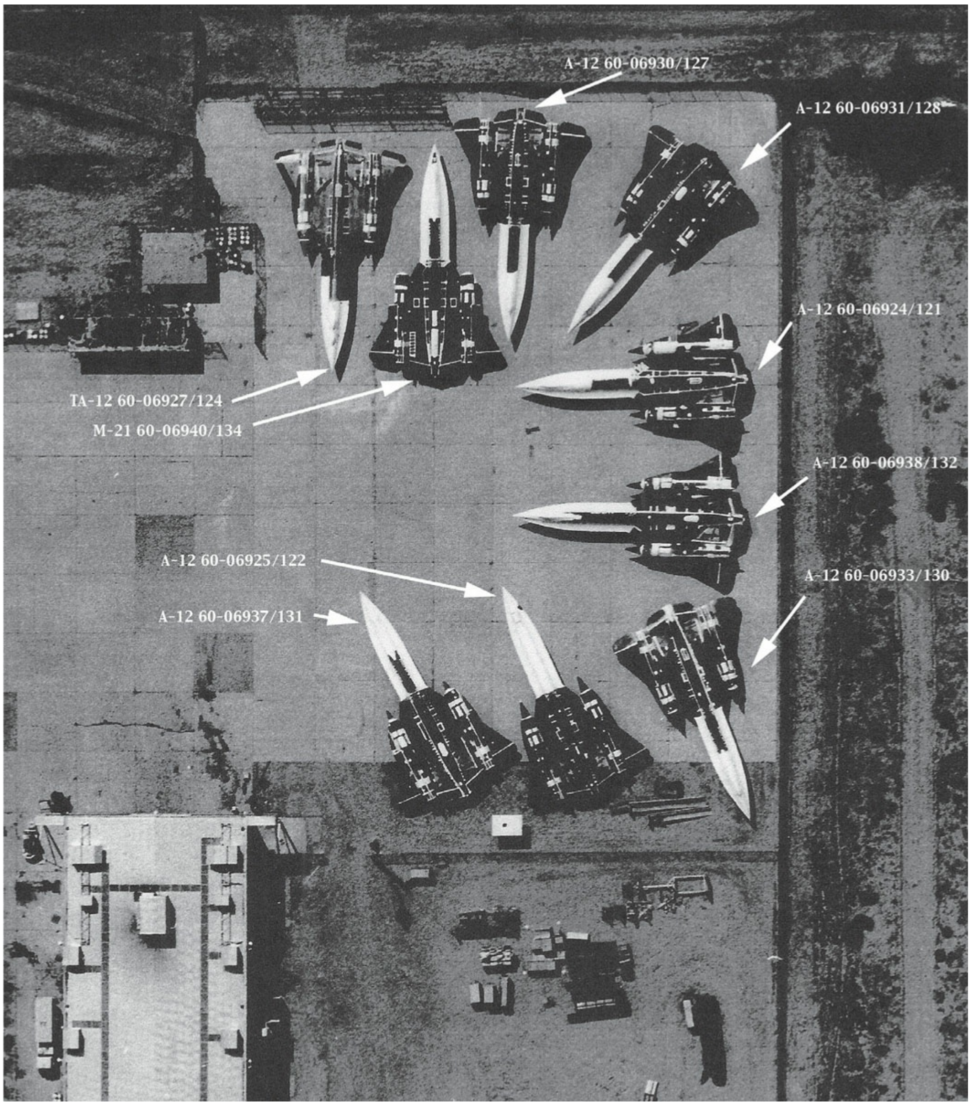
A-12 60-6926/123, photographed over the Sudan Crater on the west side of the Papoose Mountains that is the backdrop for Area 51. (Author's collection)

06928
06928

This A-12 first flew in January 1963 with Lockheed test pilot Bill Park at the controls. It was lost on takeoff at Area 51 on 28 December 1965 as a result of improper SAS wiring. (Lockheed Martin)

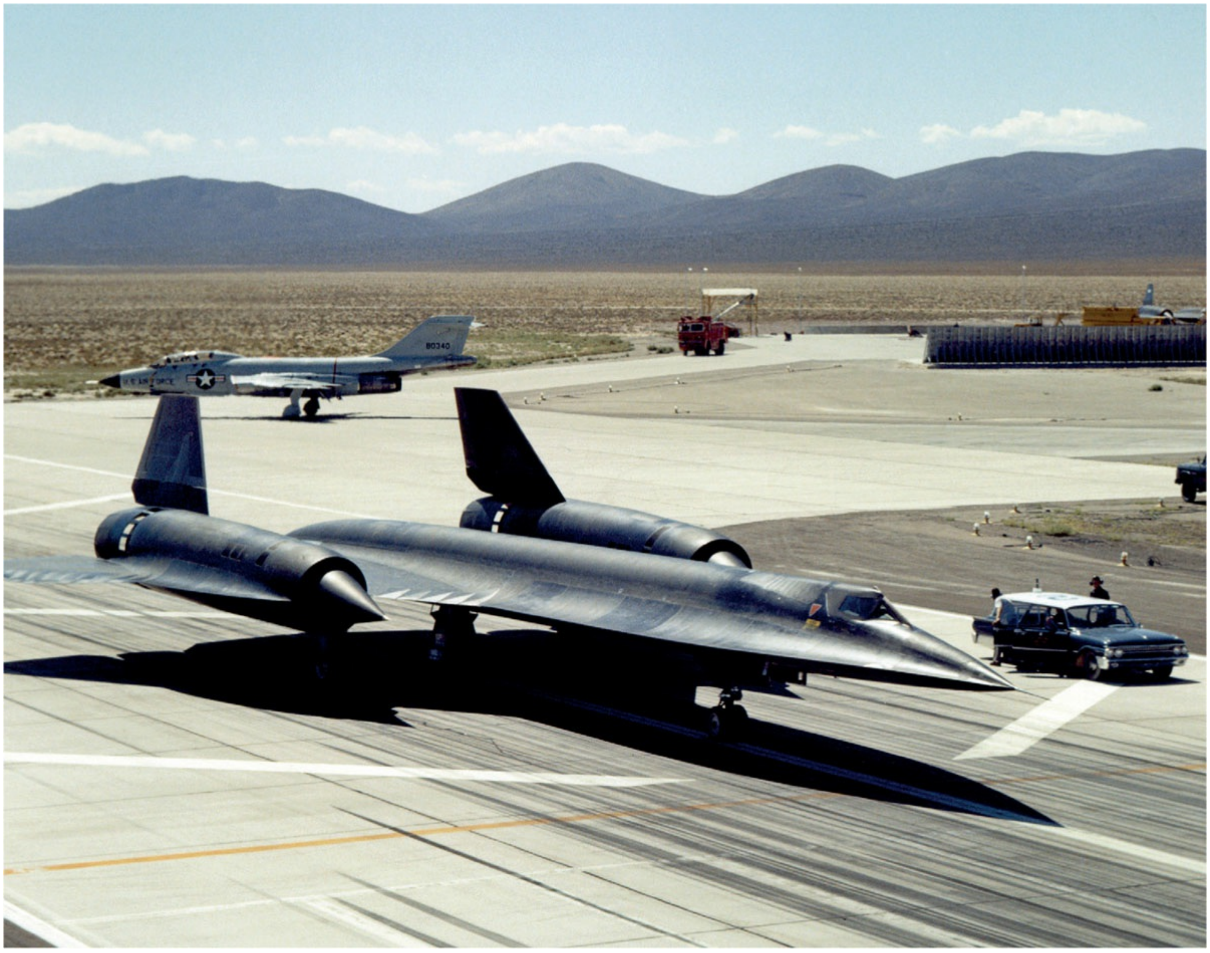


The eighth production A12, 60-6931/128, photographed on the flight line of the Minnesota Air National Guard Base, at the Minneapolis/St Paul IAP on 18 July 1992. (James C. Goodall)


A-12 60-06930/127
A-12 60-06931/128
A-12 60-06924/121
A-12 60-06938/132
A-12 60-06933/130
TA-12 60-06927/124
M-21 60-06940/134
A-12 60-06925/122
A-12 60-06937/131

This aerial photo shows the remaining nine A-12s of the 15 built, on the ramp and covered with "Spray Lat" at Air Force Plant 42, Site II, Palmdale. The author annotated it to identify which A-12s were which after his tour of Site II in August 1990. (USAF)

A-12 60-6931/128 in full Black Shield markings first flew in January 1963 with Bill Park at the controls. (James C. Goodall)



A-12 60-6930/127, photographed on the south end of the 14,000ft-long main runway at Area 51. It was the first of three A-12s to be deployed to Detachment 1 of the 1129th Special Activities Squadron, Kadena, Okinawa. Here it is readied for its five-plus-hour flight to Kadena AB on 29 May 1967. (Lockheed Martin)

YF-12A KINDLE

1963

PROGRAM: YF-12A

Name: Advanced Manned Interceptor (Kindle)

Mission: Air defense interceptor

Length: 101ft 8in (30.99m)

Wing Span: 55ft 7in (16.94m)

Height: 18ft 6in (5.64m)

Max T.O. Weight: 140,000lb (63,503kg)

First Flight: 7 August 1963

Last Flight: 17 November 1979

Crew: 2

Number Built: 3

Power Plant: 2 x Pratt & Whitney J58 (JT11D-20A) turbojet

Design Speed: Mach 3.24 (2,150mph; 3,460km/h)

Service Ceiling: >80,000ft (>24,384m)

Combat Radius: 3,000 miles (2,610nm; 4,800km)

Weapons Load: 4 x Hughes AIM-47As with 275kt (509km/h) nuclear warhead

President Johnson was briefed on the A-12 program a week after taking office during November of 1963. He reacted by directing that a formal public announcement be prepared for release at the beginning of the following year. Kelly Johnson had been invited to participate in the unveiling process on 25 February 1964 and noted, "Plans going forward for surfacing of the AF-12 program. I worked on the draft to be used by President Johnson and proposed the terminology 'A-11' as it was the non-anti-radar version."

In fact, a decision had been made to unveil the YF-12A long-range interceptor version rather than the actual A-12. The YF-12A, referred to initially by Johnson as the AF-12, had come into being during the fall of 1960 as the end product of a proposal to the Air Force for a long-range, high-speed interceptor to counter newly perceived Soviet airborne threats. During late October, a letter of intent for $1 million was delivered to Lockheed to "go forward with Plan 3A." As a result, the seventh A-12 was marked to become the AF-12 prototype.

The AF-12, as originally conceived by the Skunk Works engineering team, was a modified A-12 incorporating a fire control system integrated with a powerful new Hughes radar. A second seat in the original sensor system bay was added to accommodate a fire control system operator. During December 1960, a separate project group was organized in the Skunk Works, working independently of the A-12 team. On 23 and 24 January 1963, the first meeting with the Air Force's weapon system project office took place at Burbank and everyone was briefed on the Skunk Works aircraft design and development philosophy.

By June, AF-12 wind tunnel tests had revealed directional stability problems that resulted from the revised nose and cockpit configuration mandated by the massive Hughes AN/ASG-18 radar. For the first time, ventral fins were introduced into the design, two being in the form of fixed surfaces attached to the rear undersurface of each engine nacelle, and a third being a large, hydraulically powered, folding fin mounted on the fuselage centerline at the rear of the empennage.

The AN/ASG-18 was the first US coherent pulse Doppler radar designed for long-range, look-down or look-up detection and single target attack. It was intended for use as an air defense interceptor system and was scheduled initially for the North American F-108 Rapier.

Air Force funding allocations for construction of three AF-12s by now had cleared the way for modification of three of the CIA's original order for ten

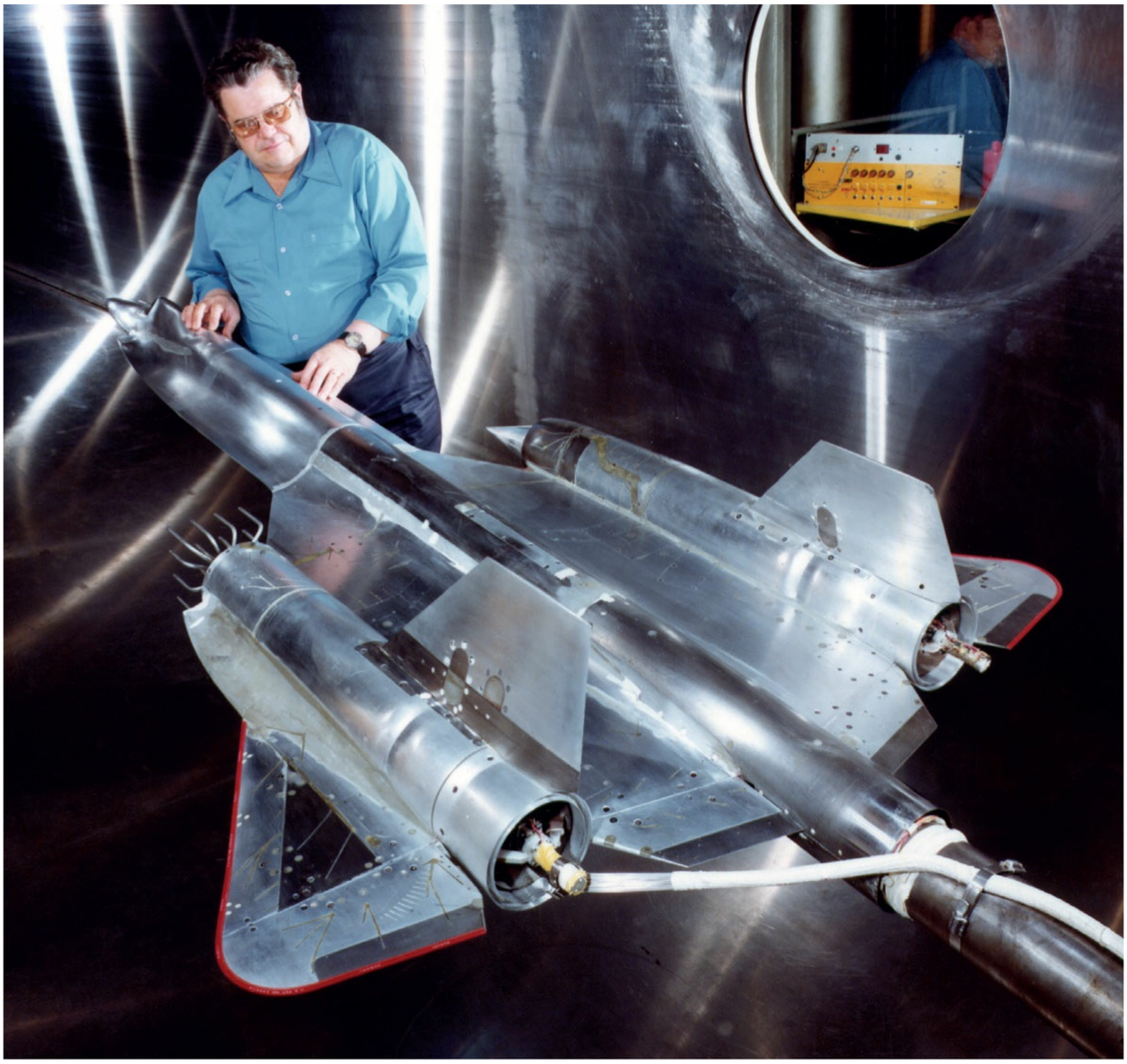
A-12s, and by 3 August 1962, the major elements of the first AF-12 were in the jig at Burbank. During September, Johnson began exploring what he called a common airframe, which would use one airframe to make either a reconnaissance and RS or an AF airplane. This would require folding the fins on the GAR-9 missile and use of a new radar antenna. It turned out very well.

From December of 1962 through early spring of 1963, construction of the three AF-12s, taking place in a segregated corner of the Burbank manufacturing facility, moved ahead with little difficulty. Discussions concerning the location of the flight-test program surfaced as a result of the security surrounding the ongoing A-12 program, and it appeared that Edwards AFB would be the best option. Regardless, at the last moment, initial flight-test activity was moved to Area 51, Nevada – the highly classified United States Air Force facility located within the USAF's Nevada Test and Training Range – and the final decision on undertaking flight-testing at Edwards was delayed.

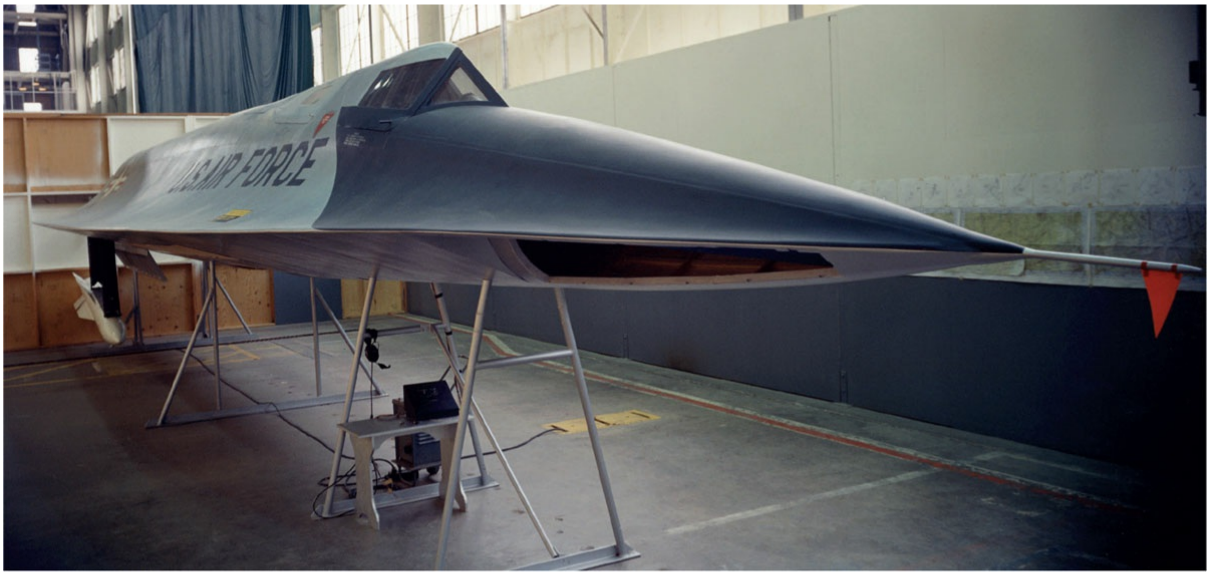
On 7 August 1963, several weeks after being moved by truck and trailer to Area 51, the first YF-12A, with Lockheed's Jim Eastham at the controls, made its first flight. Johnson would note in his AF-12 log, "It is the first airplane I've ever worked on where the fire control system was checked out prior to the first flight."

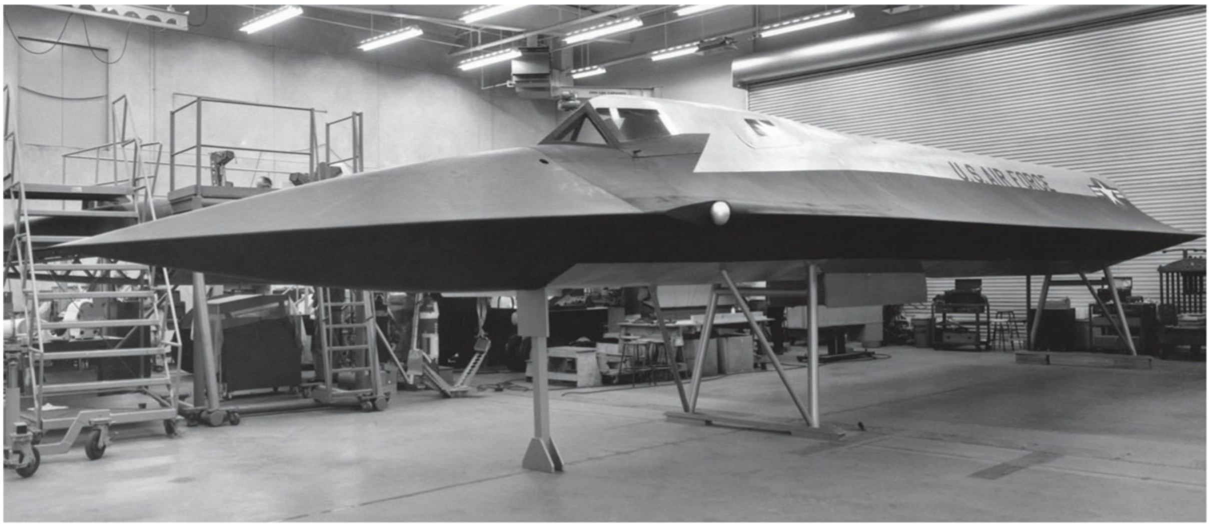
On 29 February 1964 the wraps were pulled off the A-12 program, but only partially, when President Lyndon Johnson announced the existence of the A-11 program. His announcement, made in the form of a public speech broadcast on both radio and television, stated: "The United States has successfully developed an advanced experimental jet aircraft, the A-11, which has been tested in sustained flight at more than 2,000mph and at altitudes in excess of 70,000ft.

"The performance of the A-11 far exceeds that of any other aircraft in the world today. The development of this aircraft has been made possible by major advances in aircraft technology of great significance to both military and commercial application."

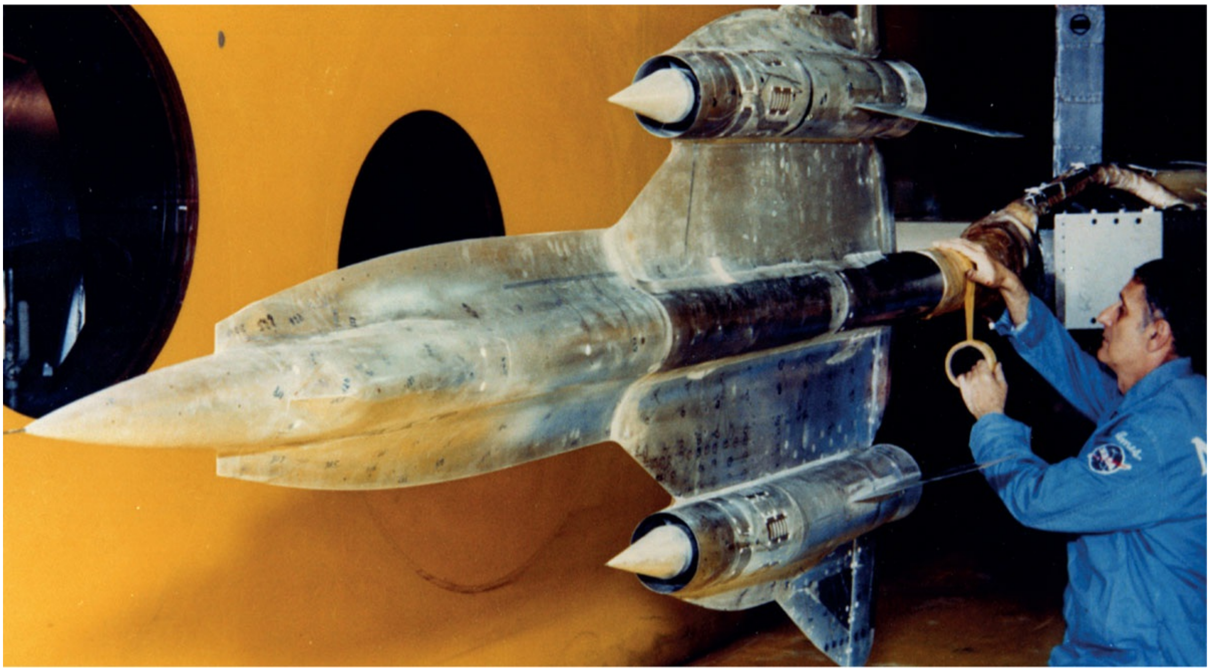


A large-scale model of the YF-12A is mounted in the high-speed wind tunnel prior to a test at Ames Flight Research Center, Mountain View. (Author's collection)

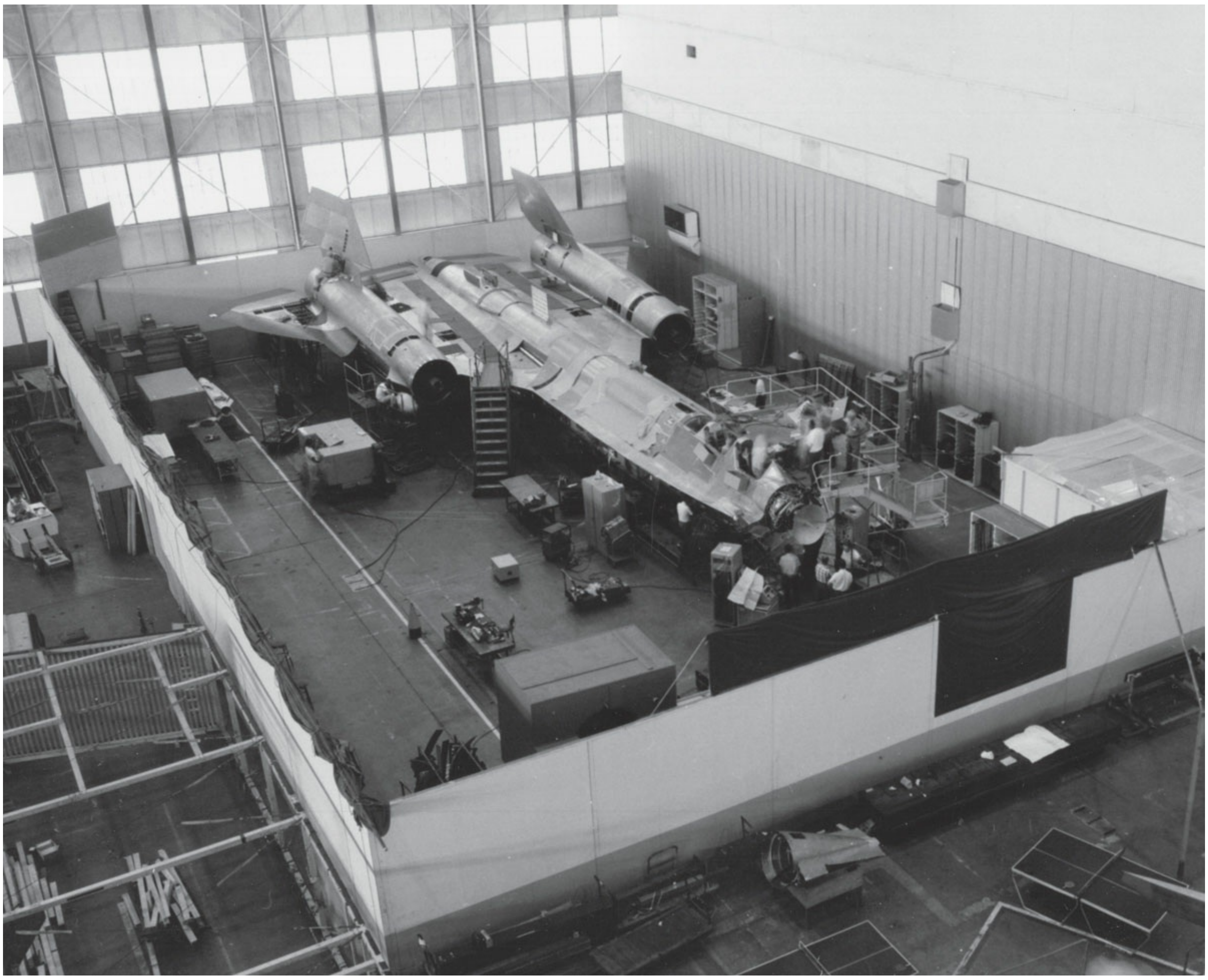




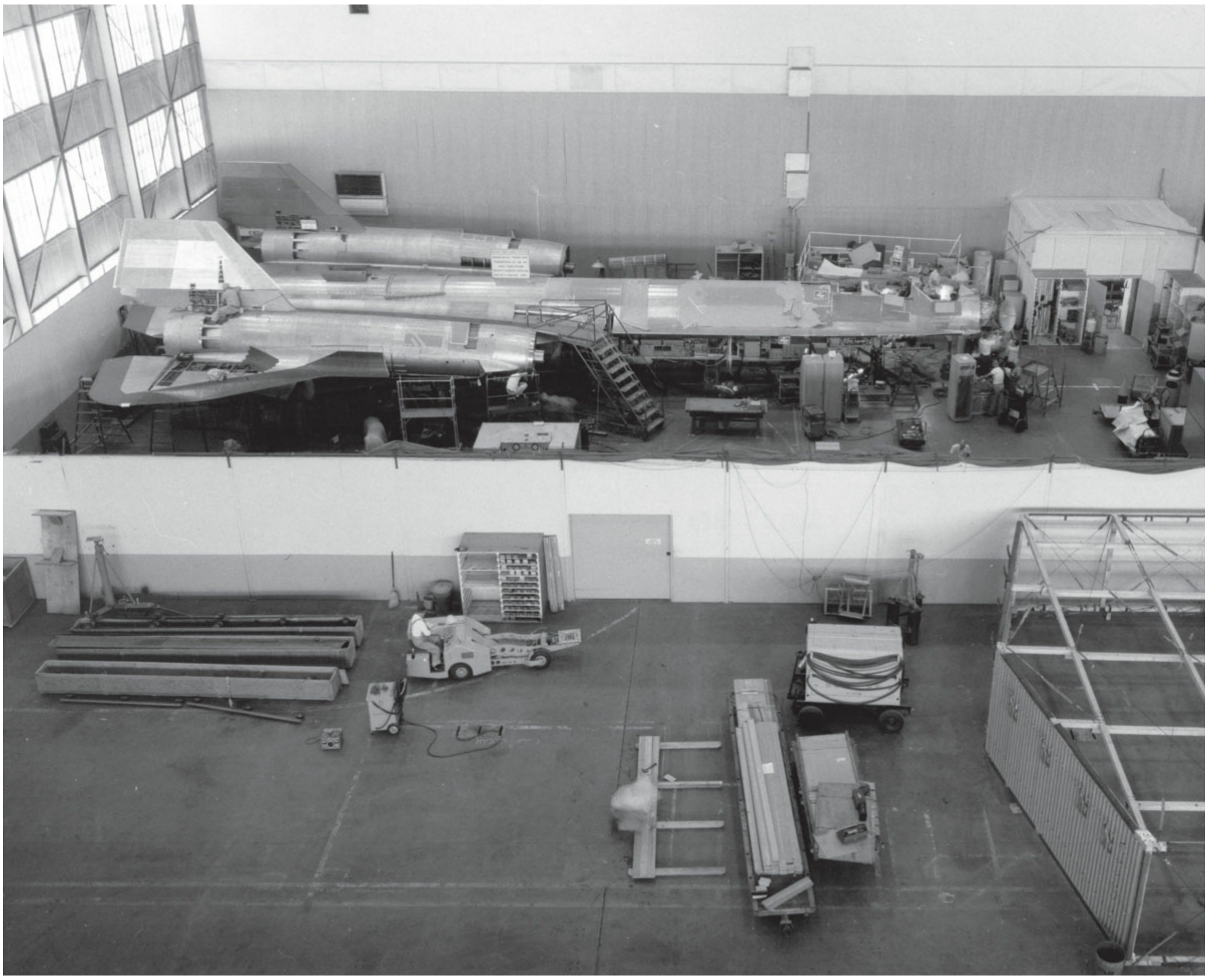
Work on the YF-12A took a slightly encouraging turn when, on 14 May 1965, the Skunk Works received a $5,000,000 contract for F-12B engineering. This aircraft, the proposed production version of the YF-12A, was configured for operational deployment and had improvements in aerodynamics and select systems. No production go-ahead was received with the engineering contract, but the expression of interest was sufficient to merit considerable optimism. (Lockheed Martin)

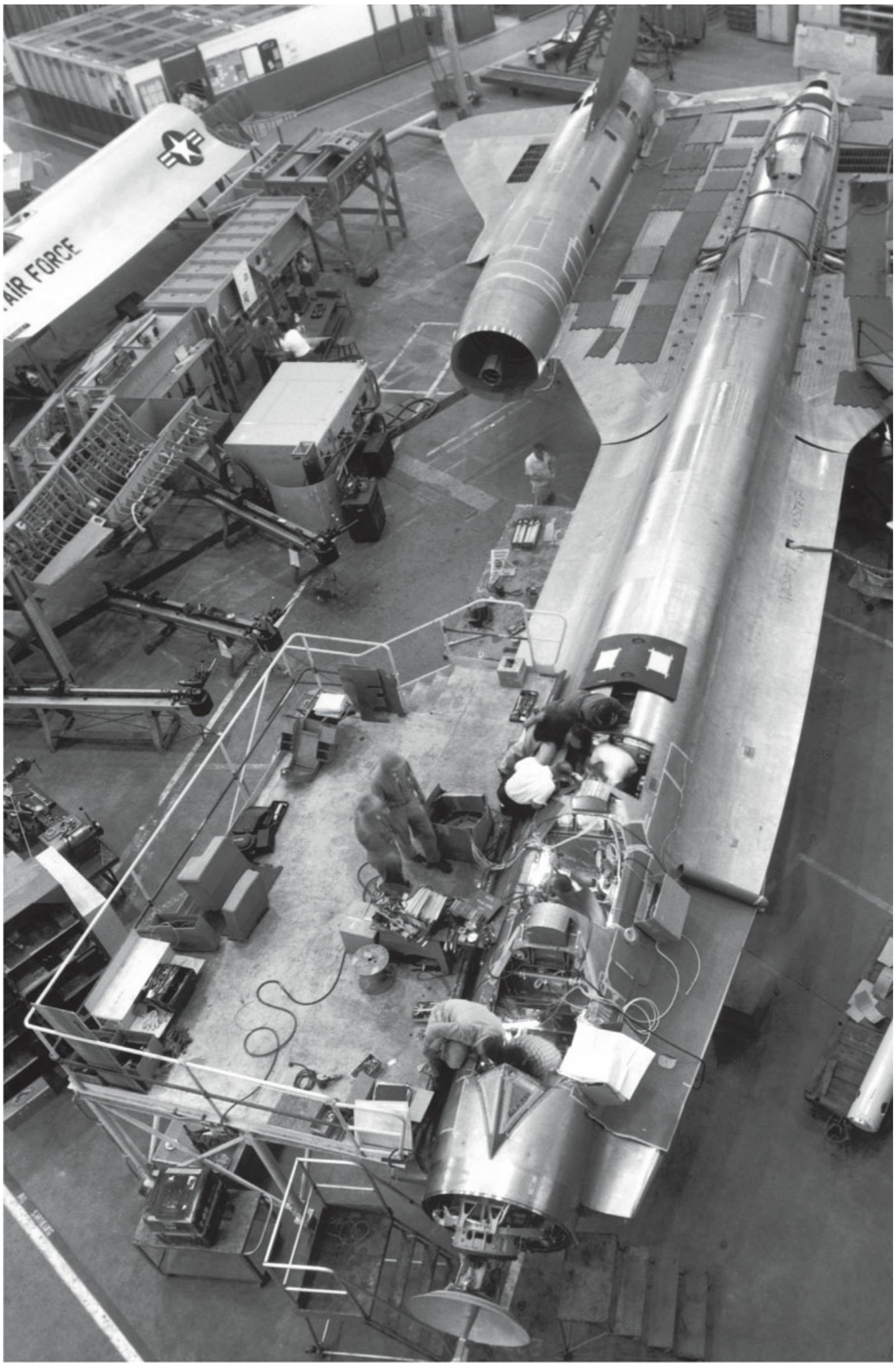


A one-twelfth scale pressure model of the YF-12A in the Ames 9 x 7ft supersonic wind tunnel. (Author's collection)

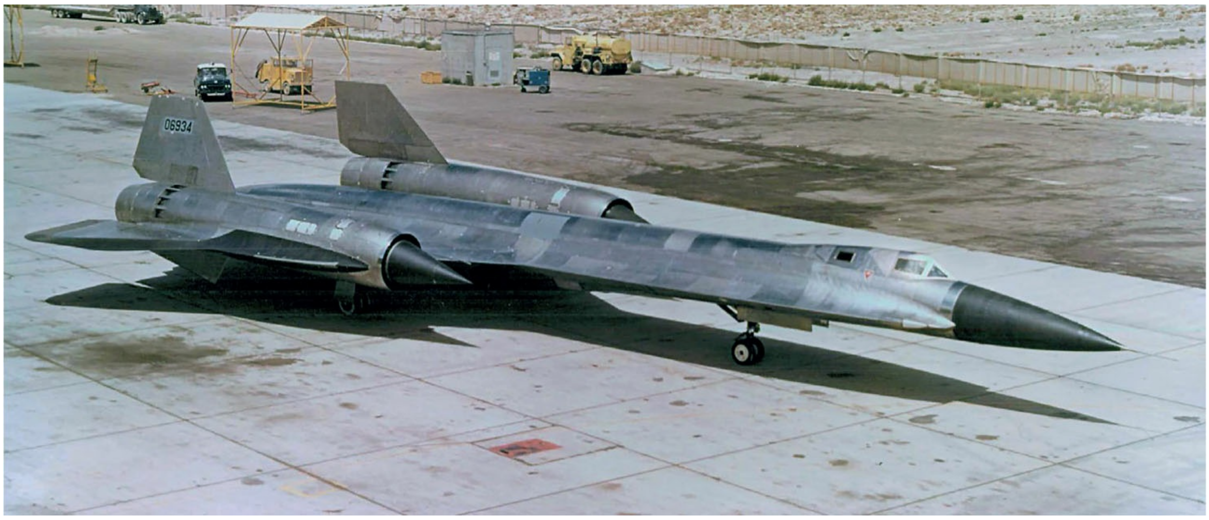


A look-down view of the second YF-12A under construction on 23 August 1963 at the Lockheed Skunk Works facility at the Bob Hope Airport, the Hollywood Burbank Airport back in the 1960s/70s. YF-12A 60-6935/1002 made its first flight on 26 November 1963 with Jim Eastham at the controls. (Author's collection)

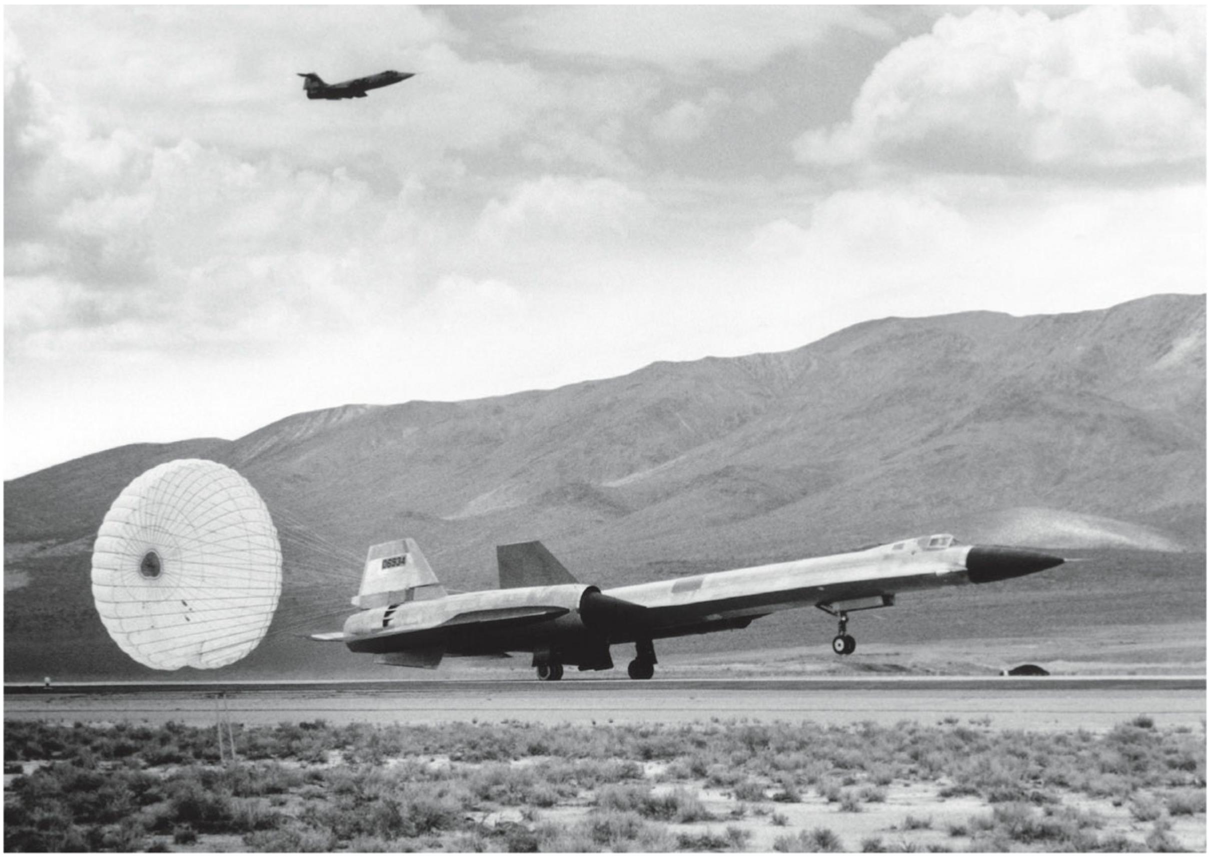




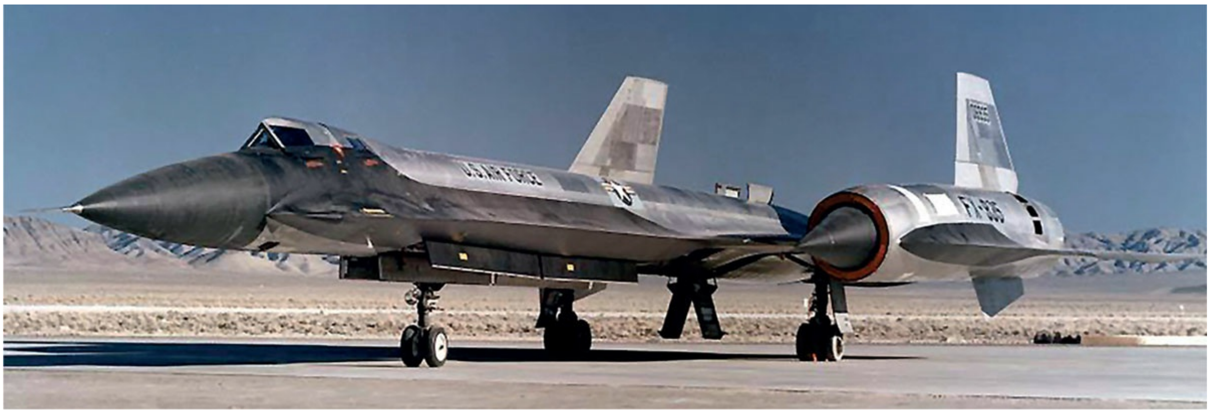
Another view of YF-12A, 60-6935/1002 from the nose looking back. On the left side of the photo is the mockup of the F-12B. This is the configuration of the F-12 if the program would have gone forward. (Author's collection)



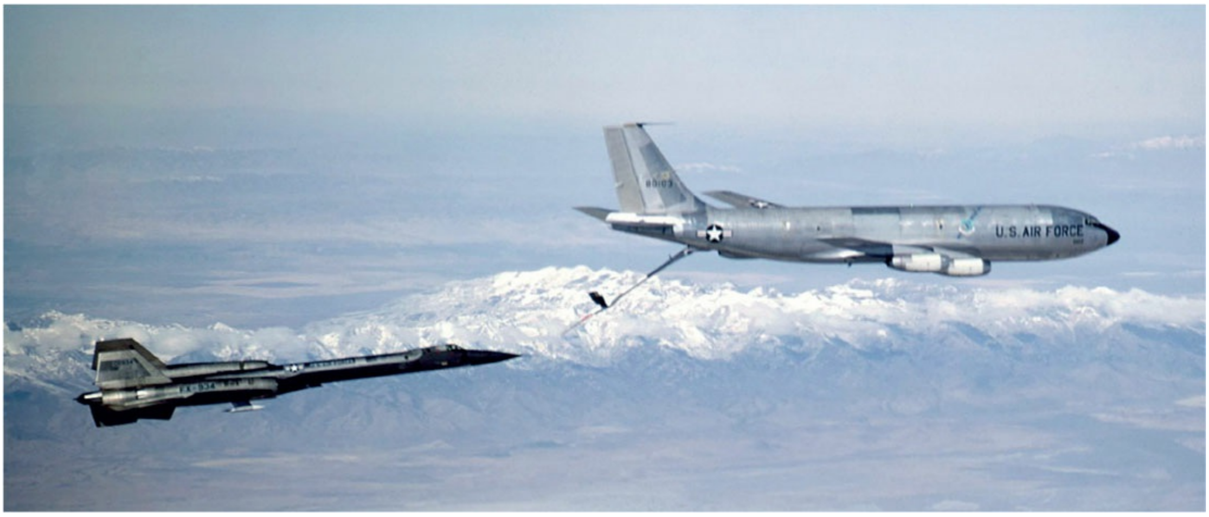
The very first YF-12A, 60-6934/1001 on the ramp of Area 51 on 7 August 1963 just before its very first flight with Jim Eastham at the controls. (Lockheed Martin)



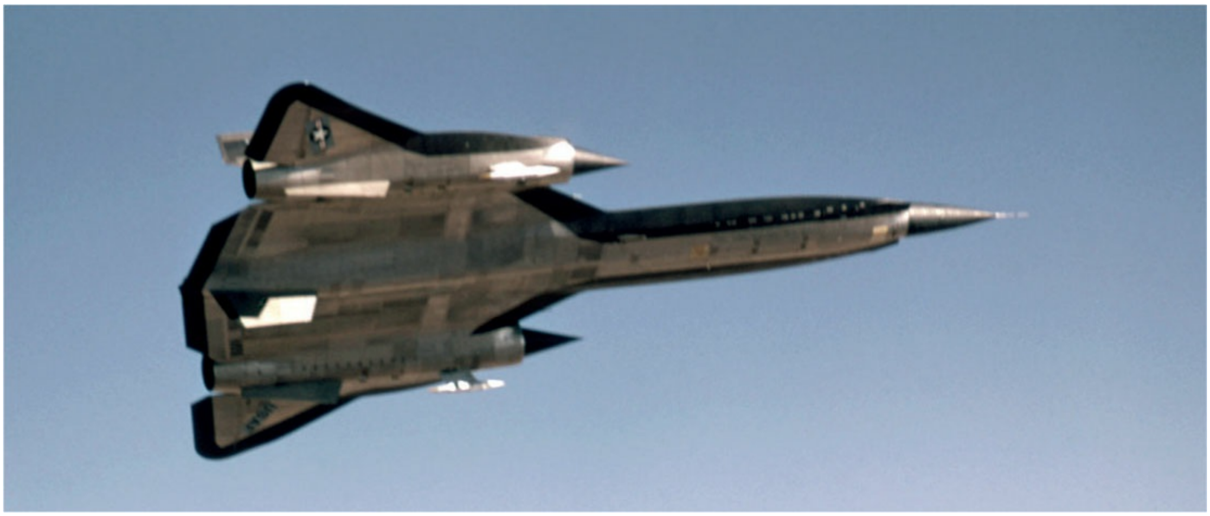
First flight of the YF-12A, 60-6934/1001, at Area 51 with Jim Eastham at the controls on 7 August 1963. Bill Park, Lockheed's chief test pilot, is in the chase F-104A. (Lockheed Martin)



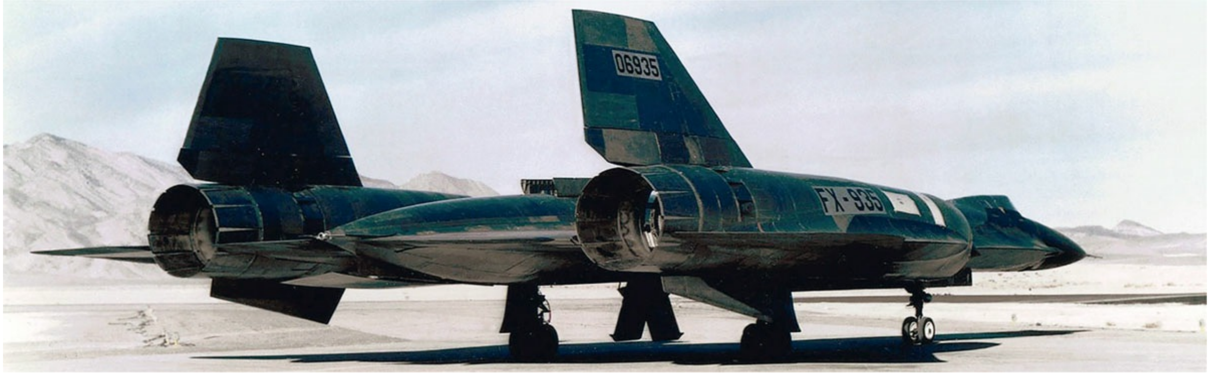
A three-quarter nose-on view of the second YF-12A, 60-6935/1002, on the north end ramp of Area 51. This is probably the best-looking shot of the YF-12 in natural metal and black ever published. (Author's collection)



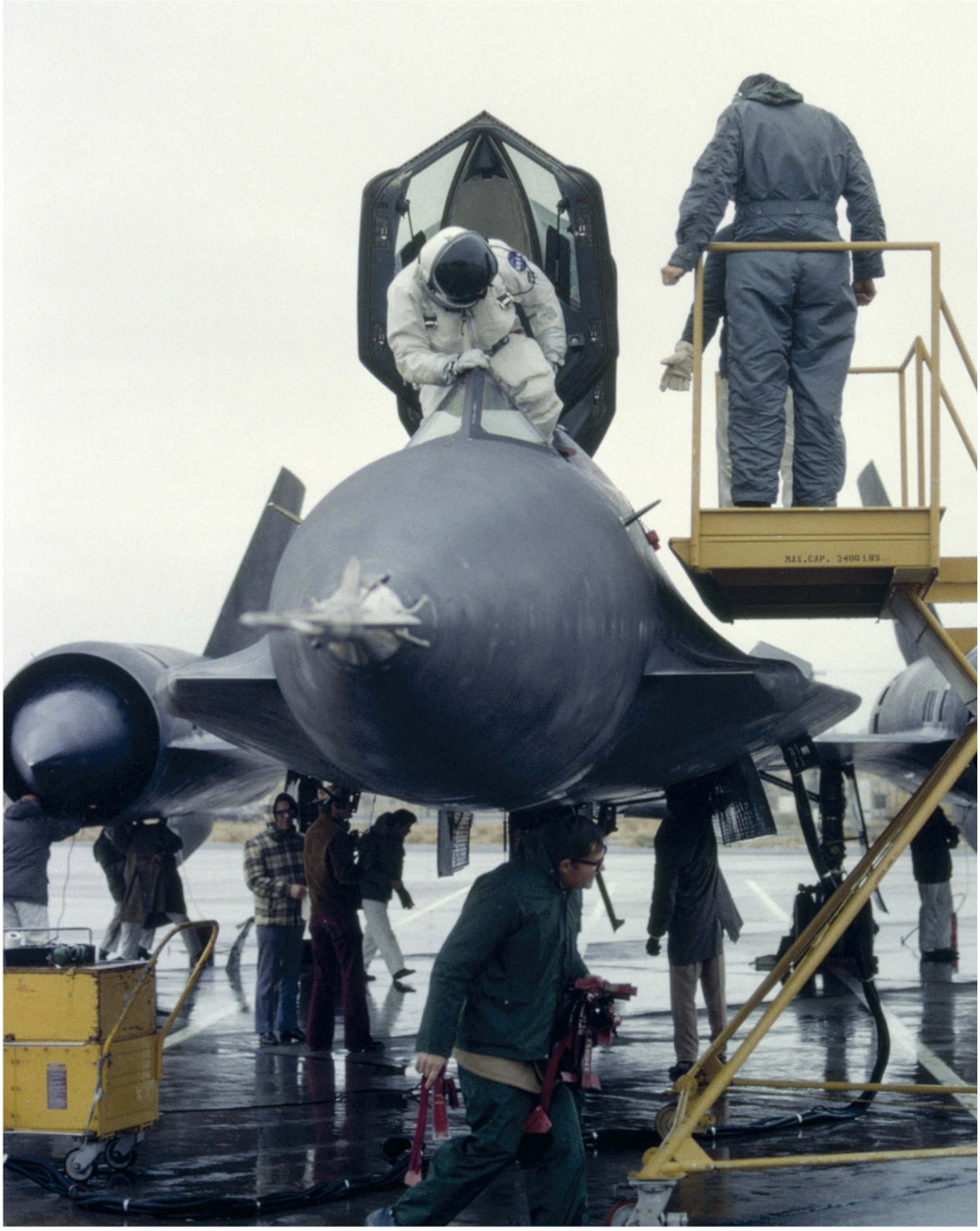
The first YF-12A, 60-6934/1001, flown by Jim Eastham and still in natural metal and black, comes in for a hookup with a Boeing KC-135A, 58-0103. (Author's collection)



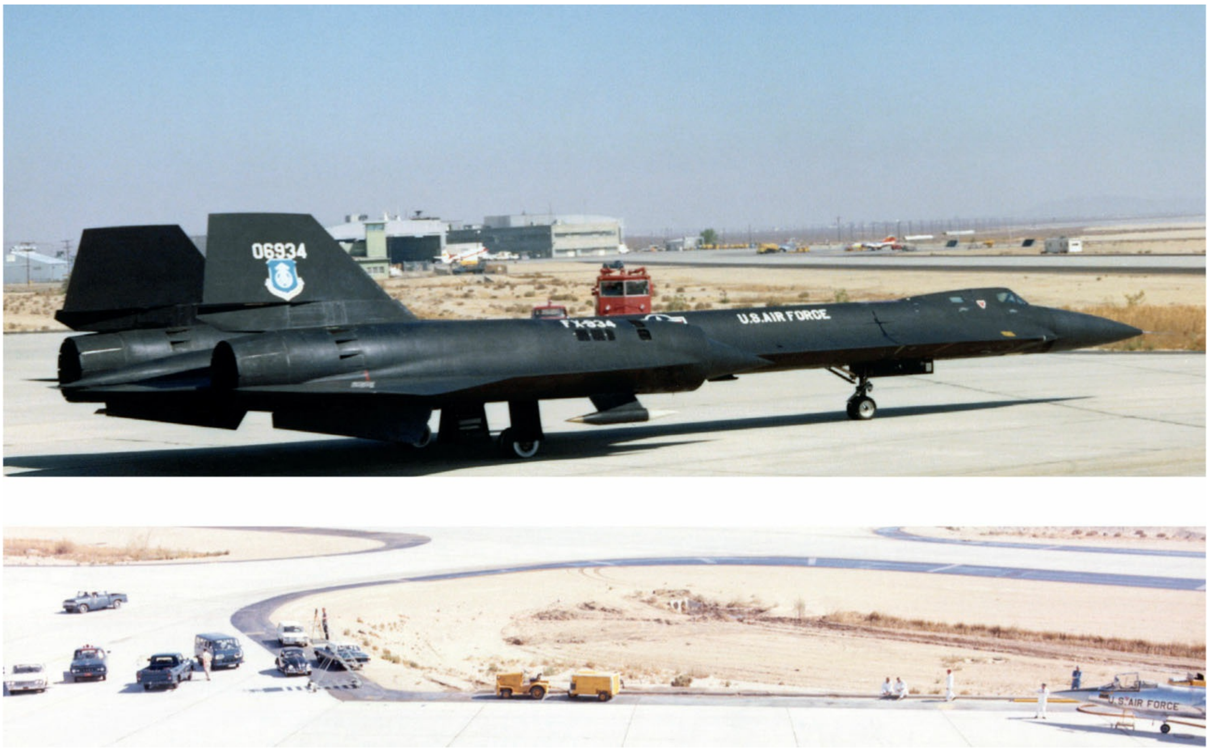
A bottom view of the number one YF-12A, 60-6934/1001, as it banks away from the photo chase plane. (Author's collection)



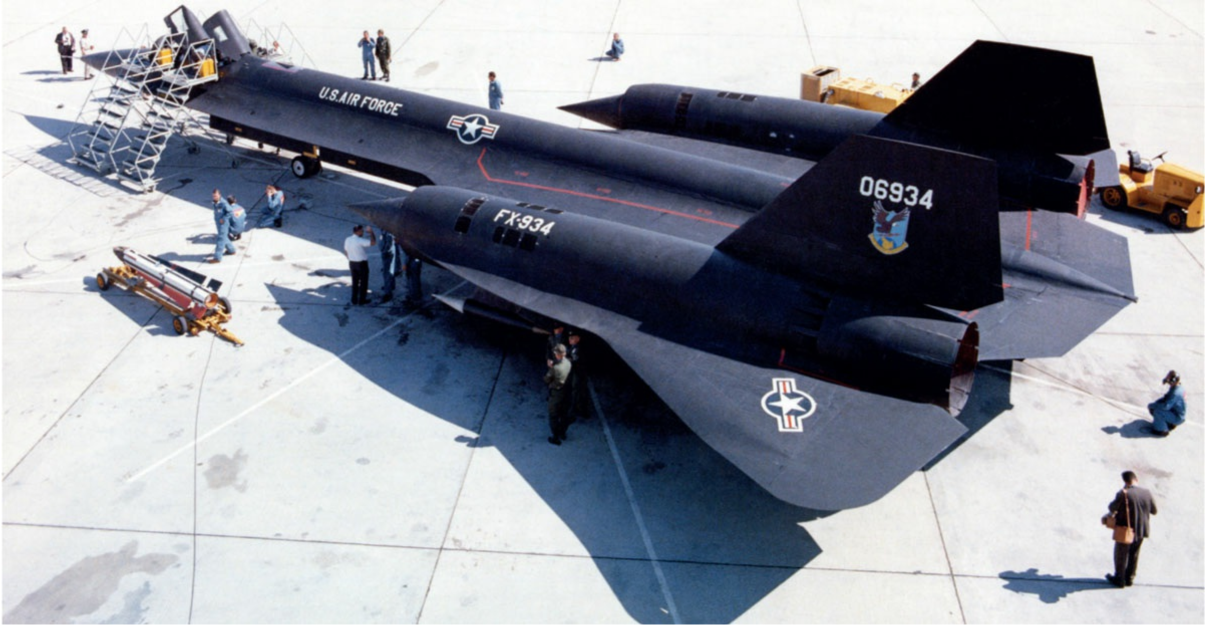
A three-quarter rear view of the second YF-12A, 60-6935/1002, on the north end ramp of Area 51. (Author's collection)


MAX.CAP. 2400 LBS.

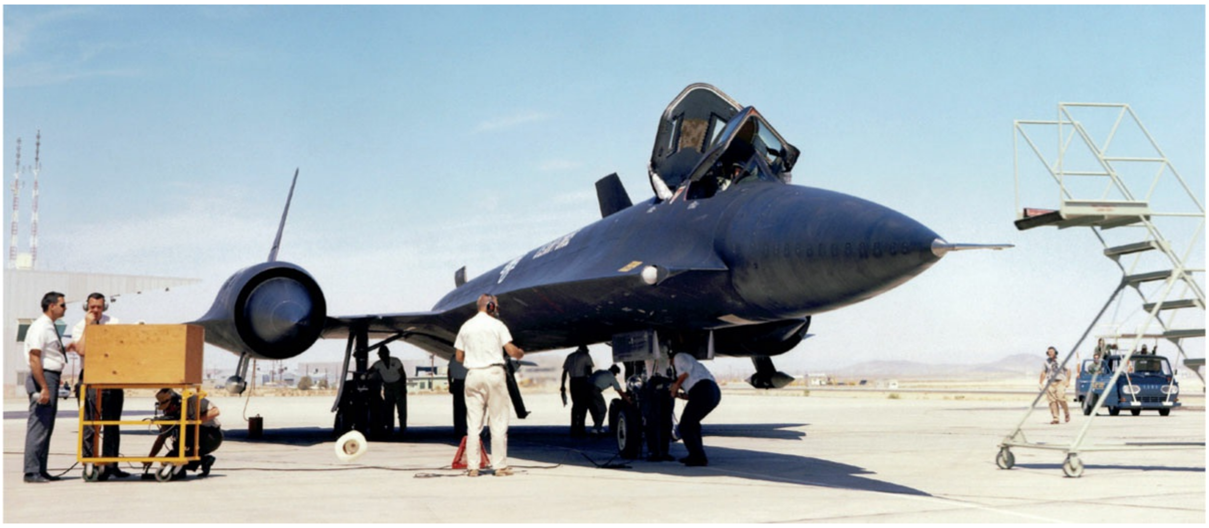
Bill Park exits the number one YF-12A 60-6934/1001 after a test run for the record run in March 1964. (Author's collection)



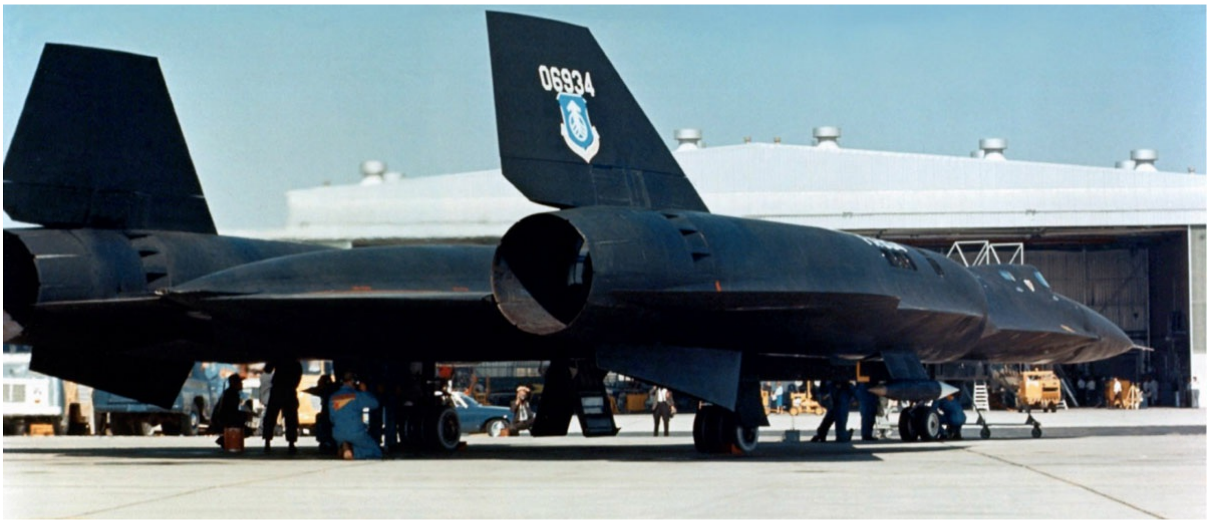
The first YF-12A, 60-6934/1001, taxis out to the main runway at Edwards AFB, carrying the Air Force System Command (AFSC) patch on its starboard vertical tail after its public unveiling on 30 September 1964. (Author's collection)



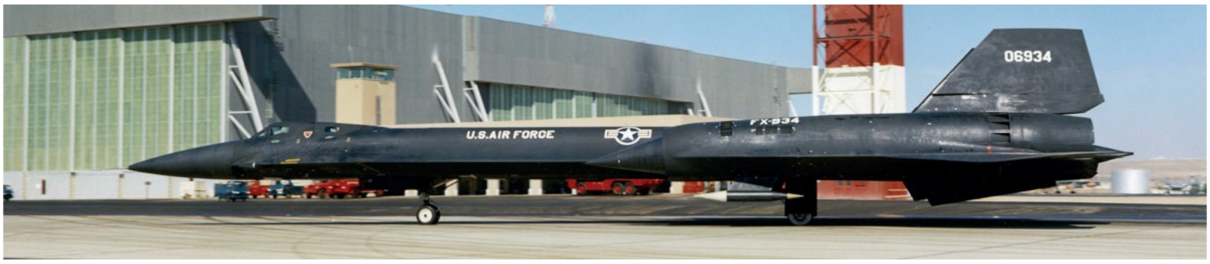
The Air Defense Command (ADC) insignia was applied on the port vertical tail of the first YF-12A, 60-6934/1001, during the Advanced Manned Interceptor (AMI) test program. This is probably the only time the ADC patch was carried on the YF-12 as it was burnt off on the first Mach 3 flight. (Author's collection)



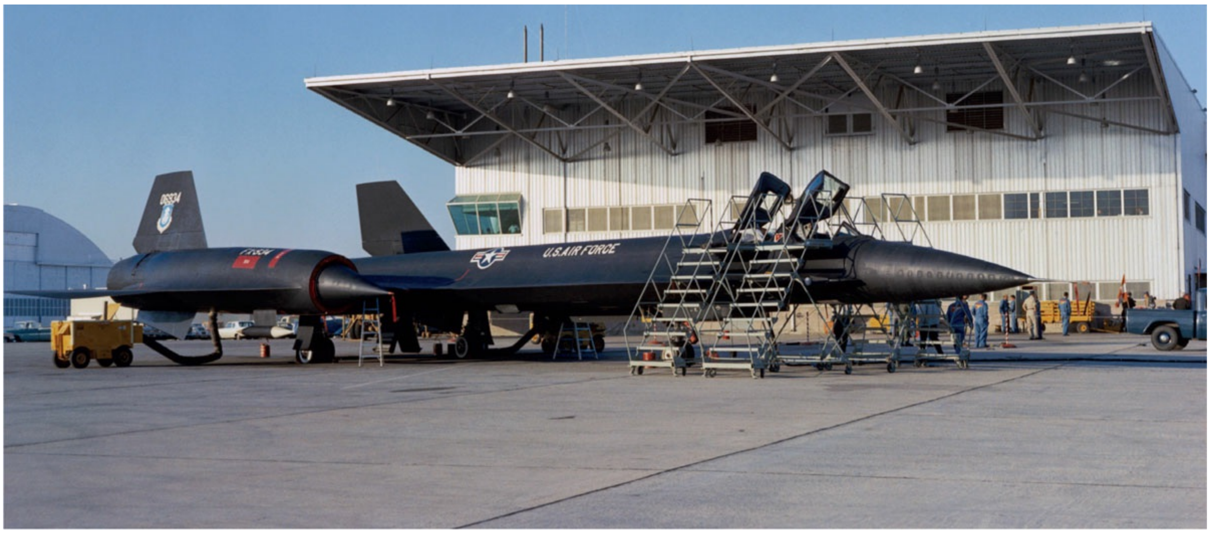
The first of three YF-12As is prepped for its very first public and press appearance on 30 September 1964. (Author's collection)



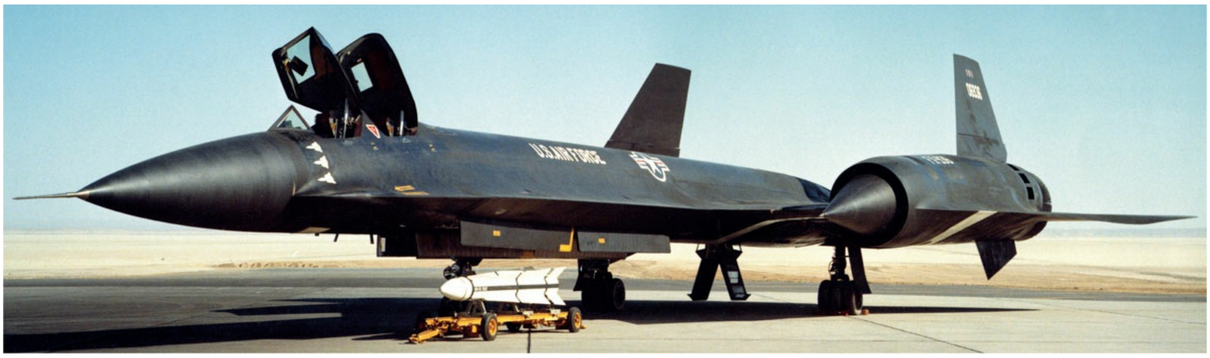
The first of three YF-12As undergoes its preflight checks at Edwards AFB during the AMI test program. (Author's collection)



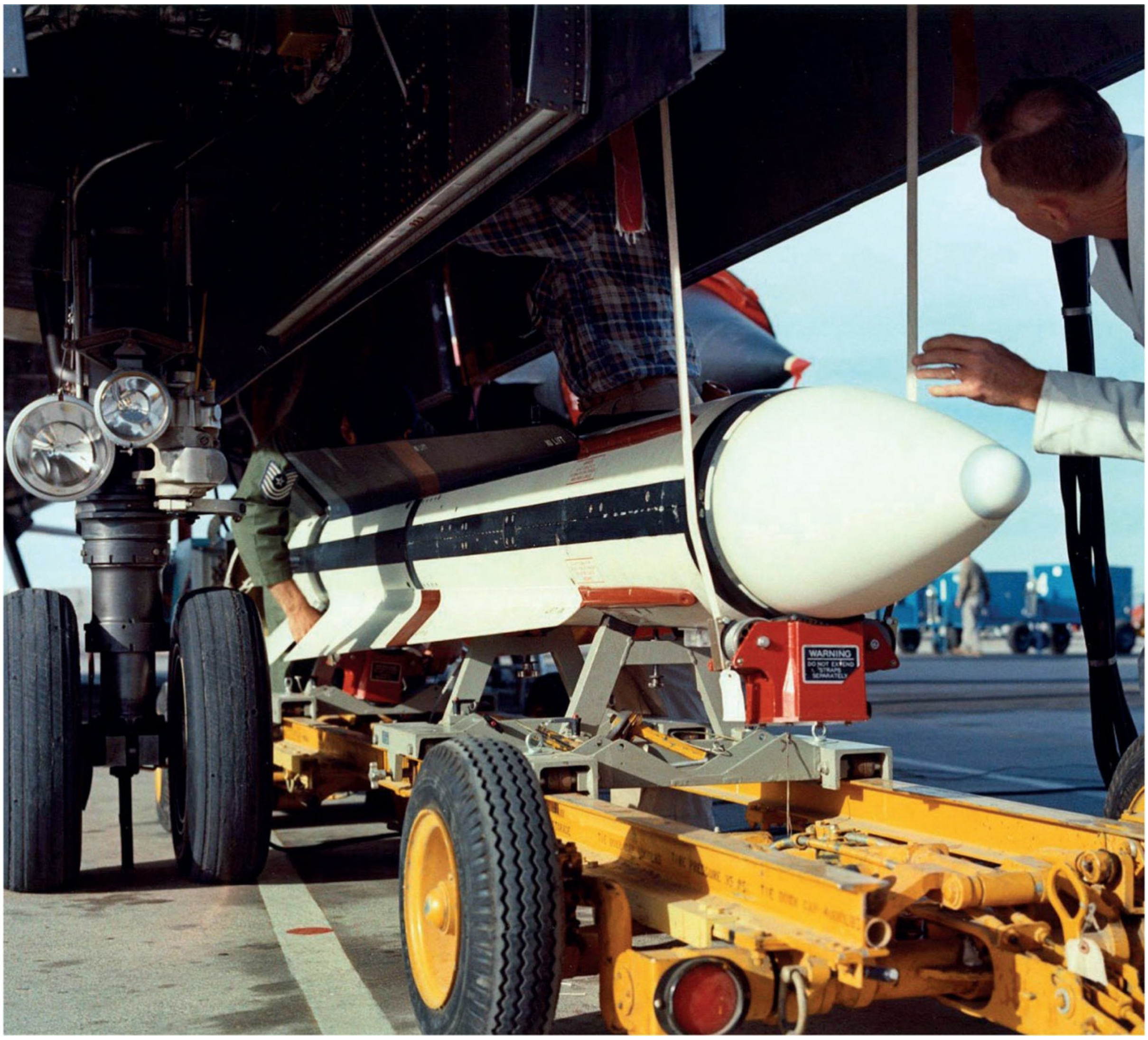
The first of three YF-12s taxis past what was then the "new" tower at Edwards AFB in the spring of 1964. (Lockheed Martin)



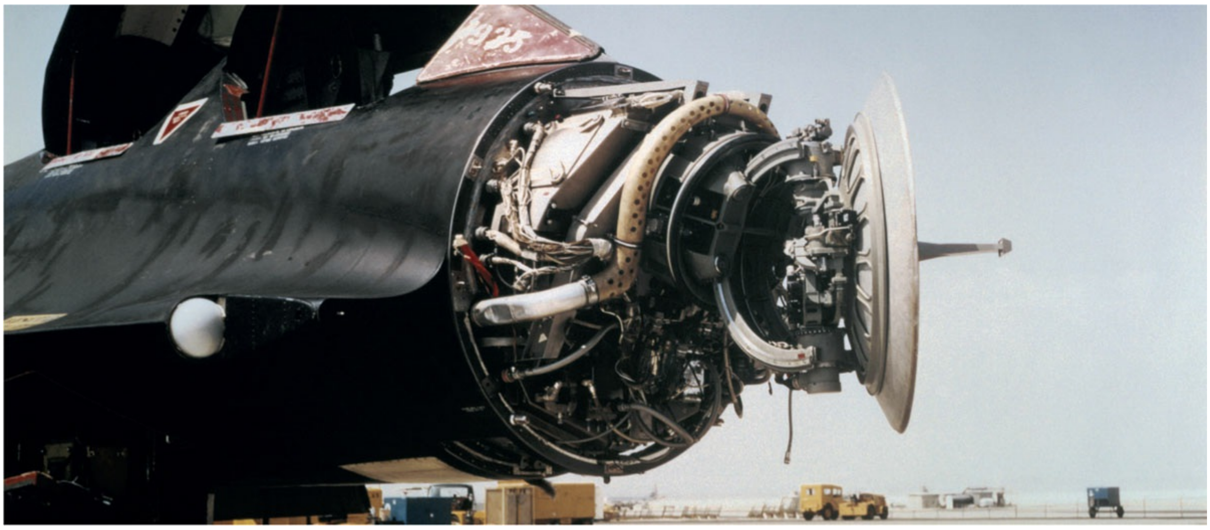
YF-12A 60-6934/1001 still carrying the AFSC patch on its starboard vertical tail. (Lockheed Martin)



On 21 September 1966, an AIM-47A was fired from YF-12A 60-6936/1003 at 3.20 Mach at 75,000ft, thus causing Kelly Johnson to note that the program finally was "hitting the high-speed corner of the design diagram." The missile missed its target at 40,000ft and at a range of 36 miles by "6 feet 6 inches ... which is a very good shot." (Lockheed Martin)


WARNING
DO NOT EXTEND
L STRAPS
SEPARATELY

YF-12A test flights continued with increasing frequency as confidence in the aircraft grew. On 16 April 1964, the first AIM-47 air-to-air missile (an inert, ballasted shell) was ejected in flight. According to Johnson, "The launching was safe but the angle developed was poor." (Author's collection)



YF-12A work had moved ahead with some difficulty during this period as well, though its problems were compounded not only by propulsion system anomalies, but also by the complexities of the AN/ASG-18 fire control system and the Hughes GAR-9 (AIM-47) air-to-air missile. (Author's collection)

D-21 TAGBOARD/SENIOR BOWL

1964

PROGRAM: D-21

Name: Tagboard

Mission: Strategic reconnaissance

Length: 42ft 10in (13.1m)

Wing Span: 19ft 0.25in (5.8m)

Height: 7ft (2.1m)

Max T.O. Weight: Launch weight 11,000lb (5,000kg)

First Flight: 22 December 1964

Last Flight: 20 March 1971

Crew: Unmanned

Number Built: 38

Power Plant: 1 x Marquardt RJ43-MA-20S4 ramjet

Design Speed: Mach 3.35 (2,300mph; 3,700km/h)

Service Ceiling: 95,000ft (29,000m)

Combat Radius: 3,500 miles (3,000nm; 5,600km)

Weapons Load: Hycon HR-335D camera system

Within Kelly Johnson's family of Blackbirds, the smallest and least known wonder was, and continues to be, the D-21. In both forms (the M/D-21 Tagboard program and the Senior Bowl operational program), this unmanned Blackbird has been carefully hidden behind a veil of secrecy for over 40 years.

Of the various Skunk Works Mach 3+ aircraft programs, the least known to reach the operational hardware stage was undoubtedly the D-21 unmanned strategic reconnaissance drone. Developed for and operated by the CIA and the Air Force under a veil of extreme secrecy not penetrated until long after the program had ceased to exist as a viable national reconnaissance asset, it was uncovered only by accident. During early 1977, aviation enthusiasts unexpectedly found 17 D-21s in storage at Davis-Monthan AFB's Military Aircraft Storage and Disposition Center (MASDC). Their discovery resulted in the first public disclosure concerning the precedent-setting D-21 and the beginning of an ongoing curiosity about its history and operational service life.

Codenamed Tagboard, the D-21 was, in fact, an extension of the A-12 program. It was brought to life in response to the US Government's decision to discontinue overflights following the loss of Francis Gary Powers in his U-2 on 1 May 1960. Consequently, in October 1962, Kelly Johnson made the first log entry in what was to become this enigmatic aircraft's long-hidden history: "Over the past several years, we have had a number of discussions on the feasibility of making a drone with the A-12 aircraft. I have steadily maintained that we should not do this, as it is a much too large and complicated machine. On several different occasions, we studied the use of a QF-104 air-launched from the A-12."

Authorization for a drone study was received by the Skunk Works from the CIA on 10 October 1962. Johnson noted the event as follows: "We have now configured it to allow the use of plastic blankets overall for the basic structure. In order to avoid the F-104 problem of a high central vertical tail, I put two on the tips and one in the middle. Besides the aerodynamic benefits of this configuration, they will provide the basis for a landing gear during the flight test operation."

Coupled with propulsion technology developed by Marquardt, it was not difficult for the team to execute a functional reconnaissance platform in a relatively short period of time. Importantly, the technology base generated by initial flight-tests of the A-12 had given the engineering team considerable confidence in the aerodynamic and low-observables precedent (i.e. reduced radar cross section) set by the chined delta. This configuration was a given by the time initial design options were studied for the D-21.

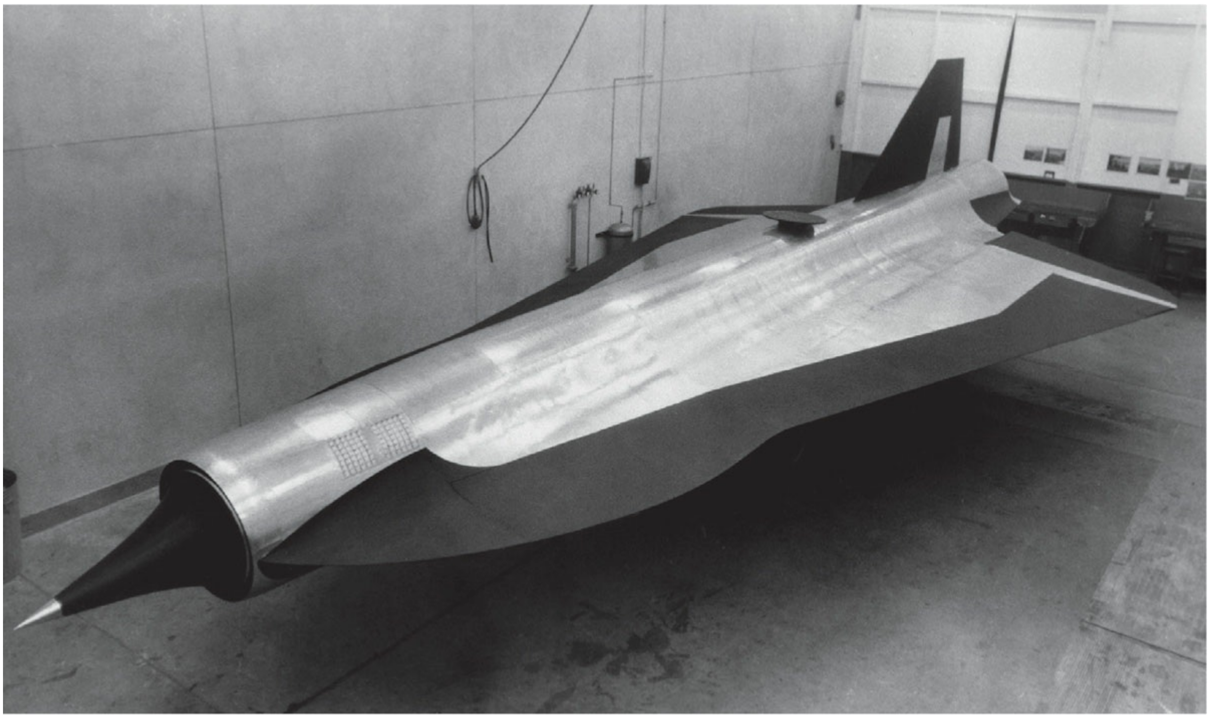
On 24 October 1962, Johnson, Ben Rich and Rus Daniell met with representatives from Marquardt to discuss the use of a ramjet propulsion system on the new Lockheed drone. Johnson wrote: "It is obvious that we cannot use the Bomarc engine without change. We will just do the best we can to use its major parts."

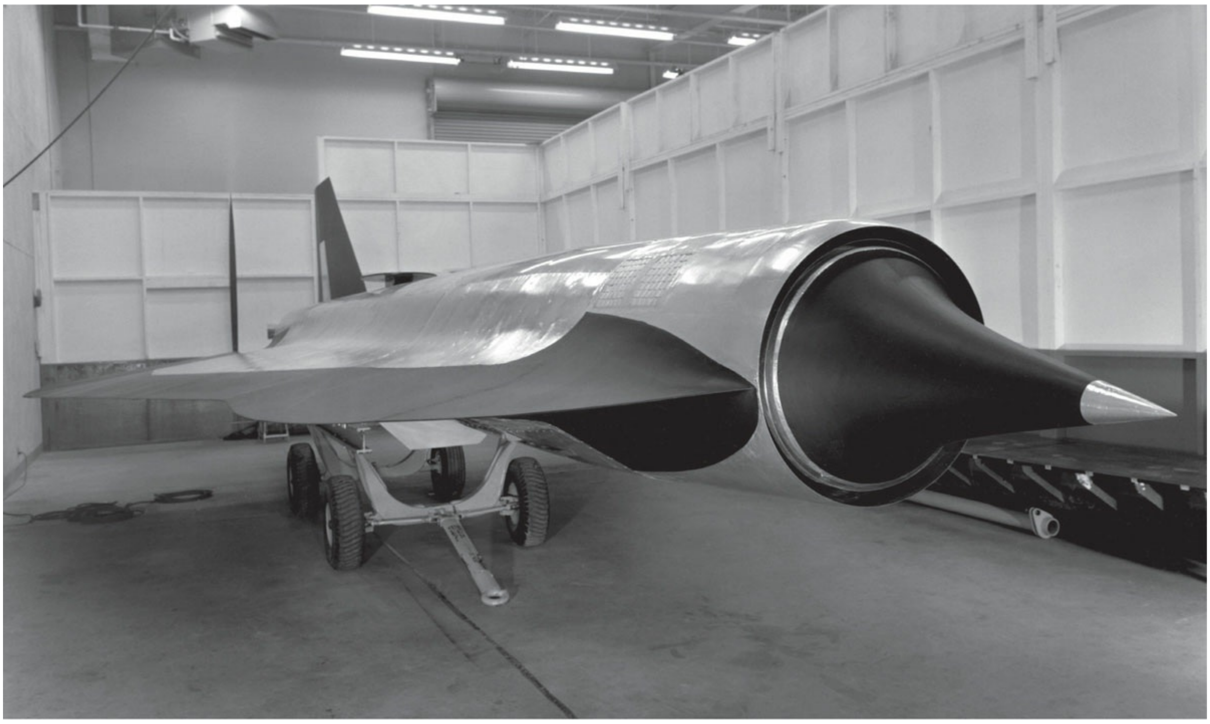
A small team was assembled to handle engineering and a piece of the Skunk Works shop at Burbank was walled off specifically to accommodate the new drone activity.

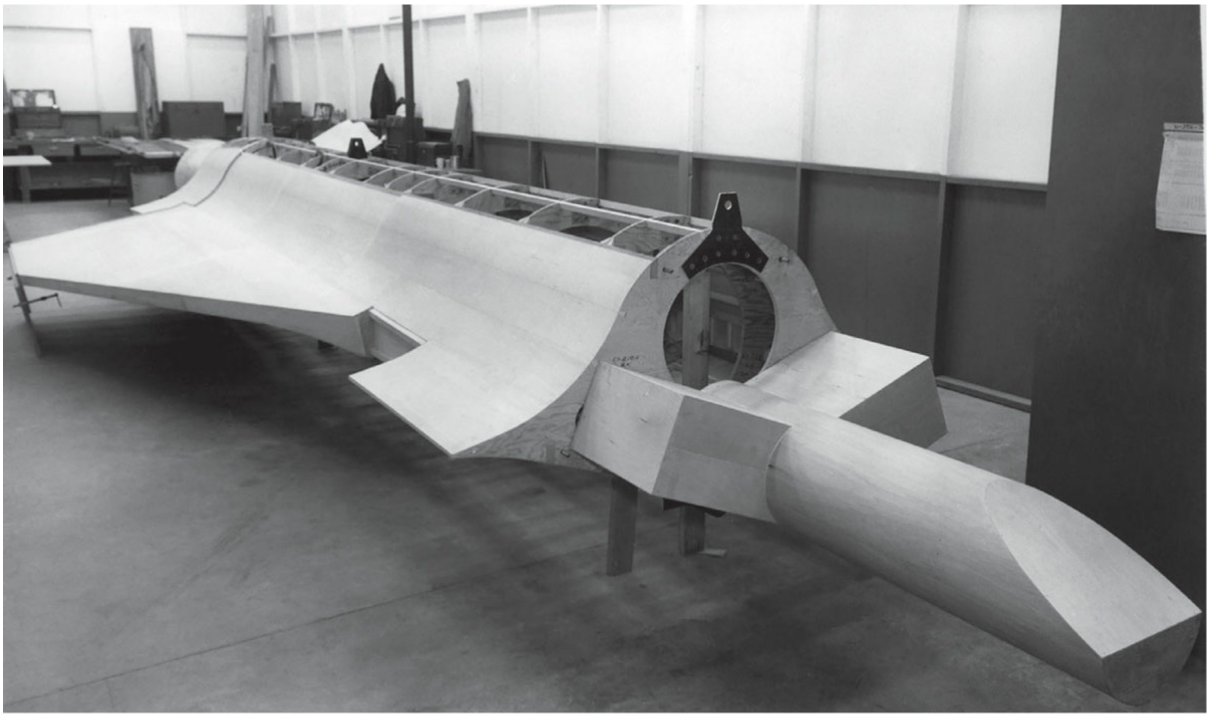
The D-21 engine is properly identified as an XRJ43-MA-20S4. While the Bomarc A used Marquardt RJ43-MA-3 ramjet engines, the Bomarc B used two externally mounted RJ43-MA-11s. Each MA-11 engine had a fixed geometry, Mach 2.35, isentropic spike inlet. The engine's integral combustion chambers/exit nozzles were designed for relatively low cruise altitudes and therefore did not require high-expansion-ratio nozzles. The ignition system in each engine consisted of two pyrotechnic flares. There was no re-ignition capability. The MA-11's fuel control and flame holder combustion limits would not allow operation at high altitudes.

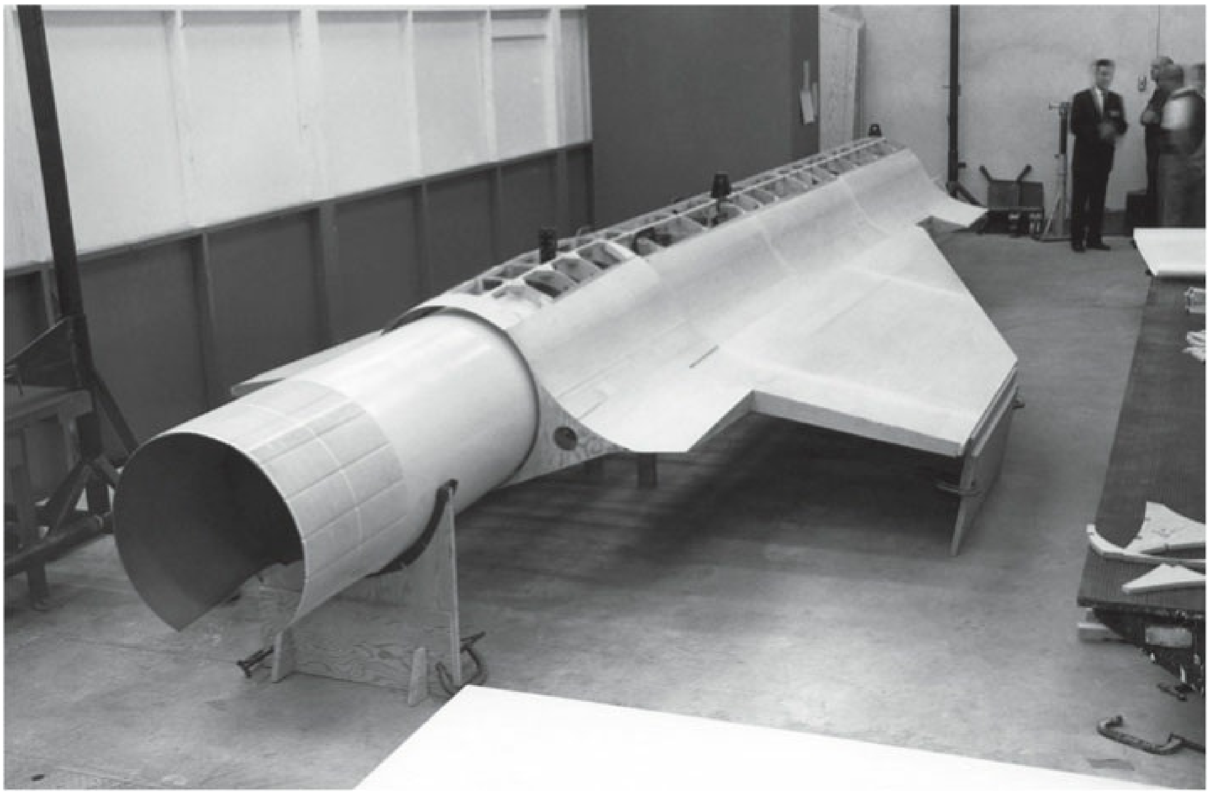
The externally mounted MA-11 engines on the Bomarc B used an all-pneumatic fuel control system that maintained a constant Mach number of two selectable speeds as determined by pressure signals from the built-in inlet. These engines had the ability to function as an independent external power plant on any vehicle that could each provide sufficient speed to allow efficient inlet operation. The MA-11 was developed in supersonic wind tunnels at Marquardt's Van Nuys, California, test facility, flight-tested on the Lockheed X-7A-3 at Holloman AFB, Alamogordo, New Mexico, and deployed operationally on the Bomarc B.

The MA-20S4 engine employed in the D-21 used many MA-11 components but was modified to operate at lower pressures and higher temperatures. The S4 was immersed in the body of the D-21 and had no inlet structures of its own because it utilized the D-21's inlet system. The engine's center body and main structure remained to house the fuel control, fuel pump, fuel injector nozzles and flame-holder assemblies. The D21's XRJ-MA-20S4 would be powered up during its entire flight of over 1.5 hours.

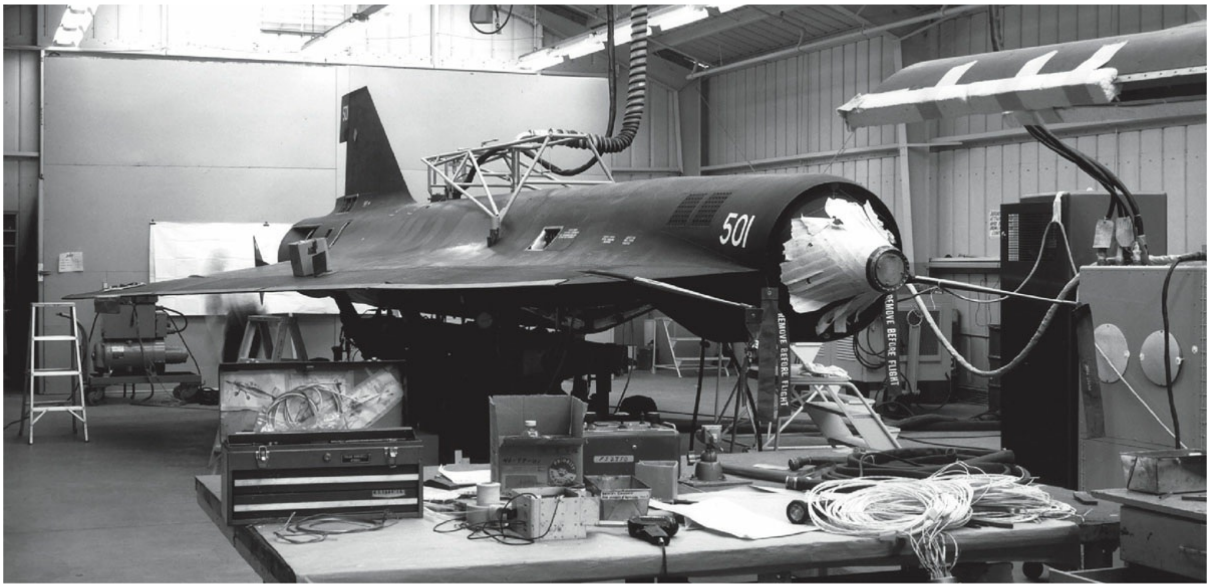




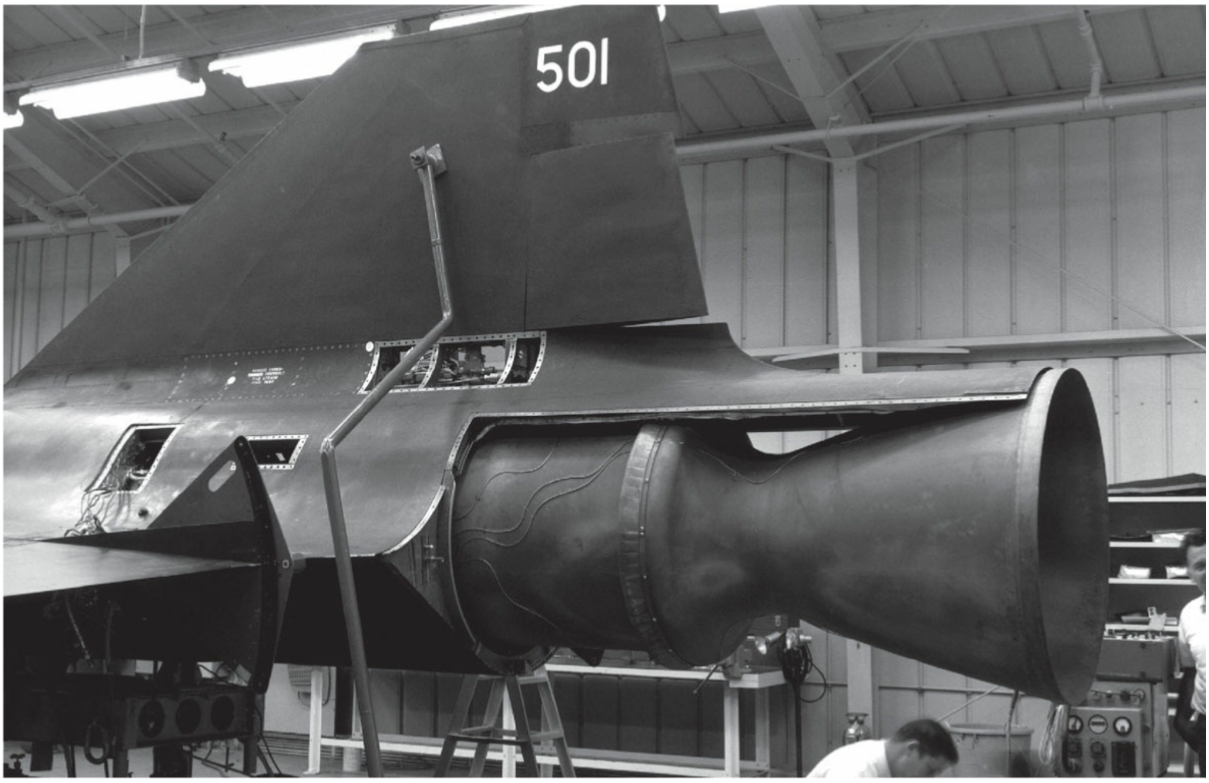




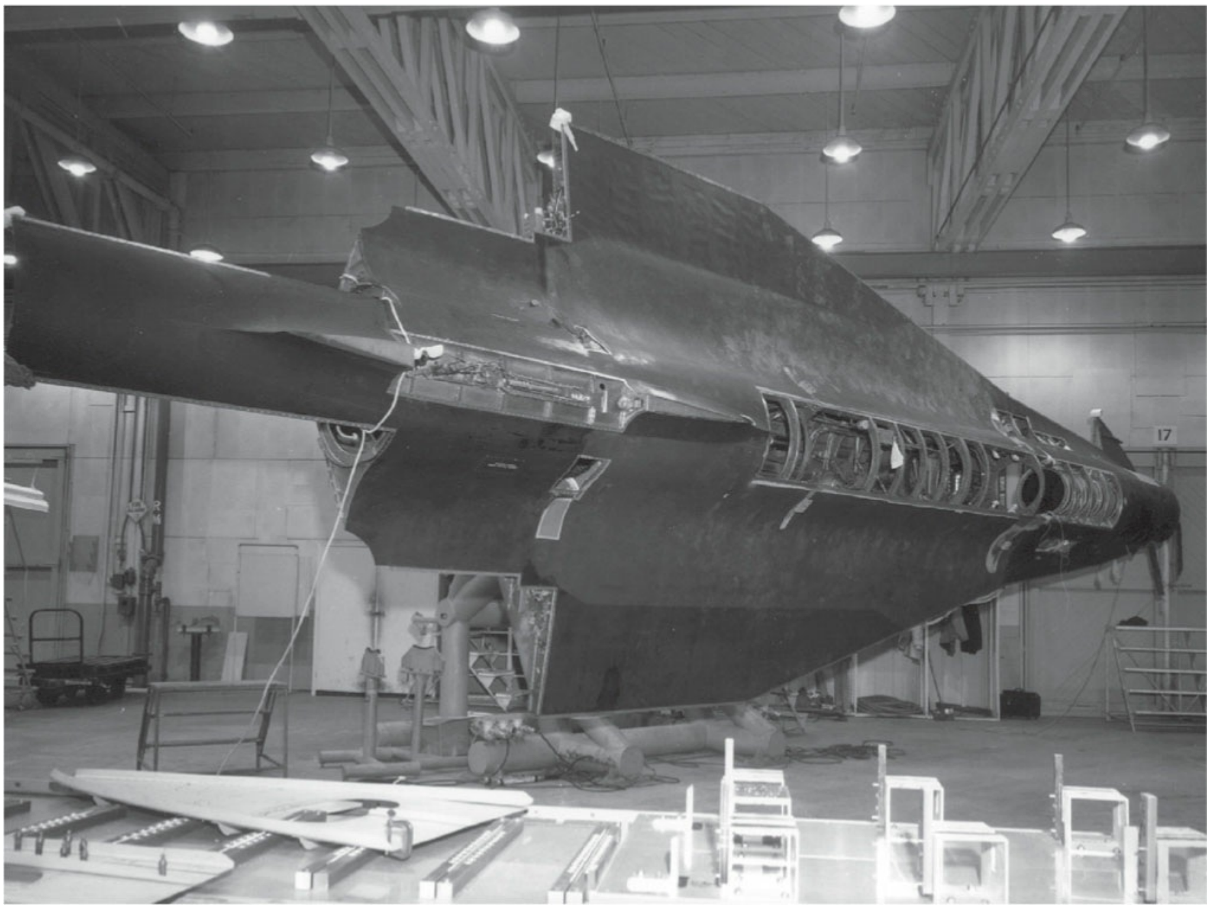
This series of photos, taken in early 1962, shows the buildup of the D-21 mockup, made mostly of wood and aluminum sheet metal. (Author's collection)


501
REMOVE BEFORE FLIGHT
REMOVE BEFORE FLIGHT

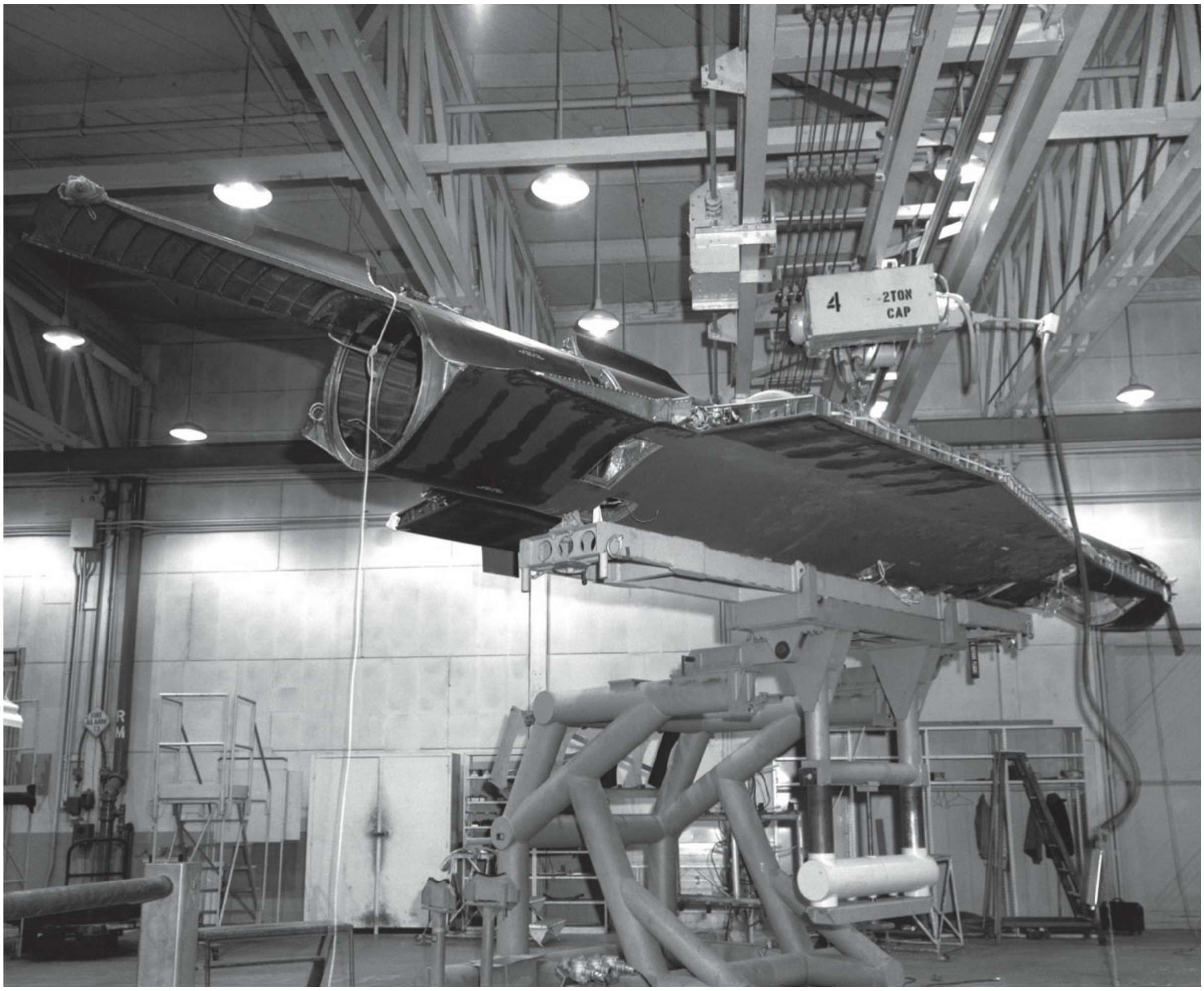
The beginning of the D-21B modifications at the Lockheed Skunk Works, Building 82, then located at the Hollywood Burbank Airport in April 1967. Shown here is the very first D-21, 501, being modified to "B" standards. (Author's collection)



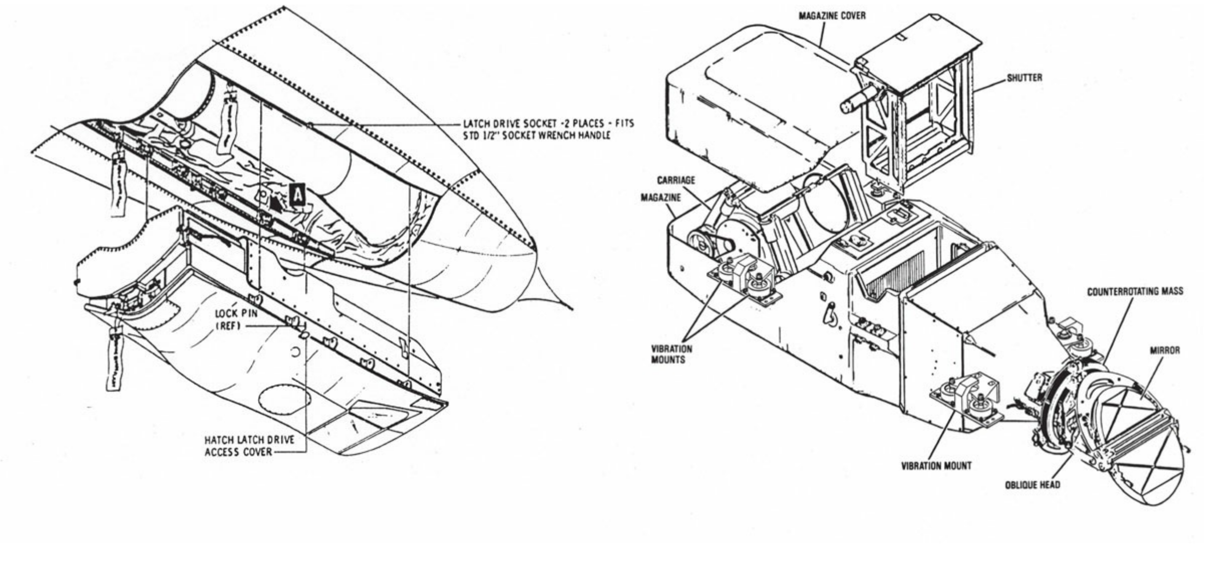
The first D-21B, 501, with its Marquardt XRJ43-MA-20S4 ramjet exposed. This engine was run and damaged during a captive engine run test in which D-21 503 was also damaged and not launched. (Author's collection)



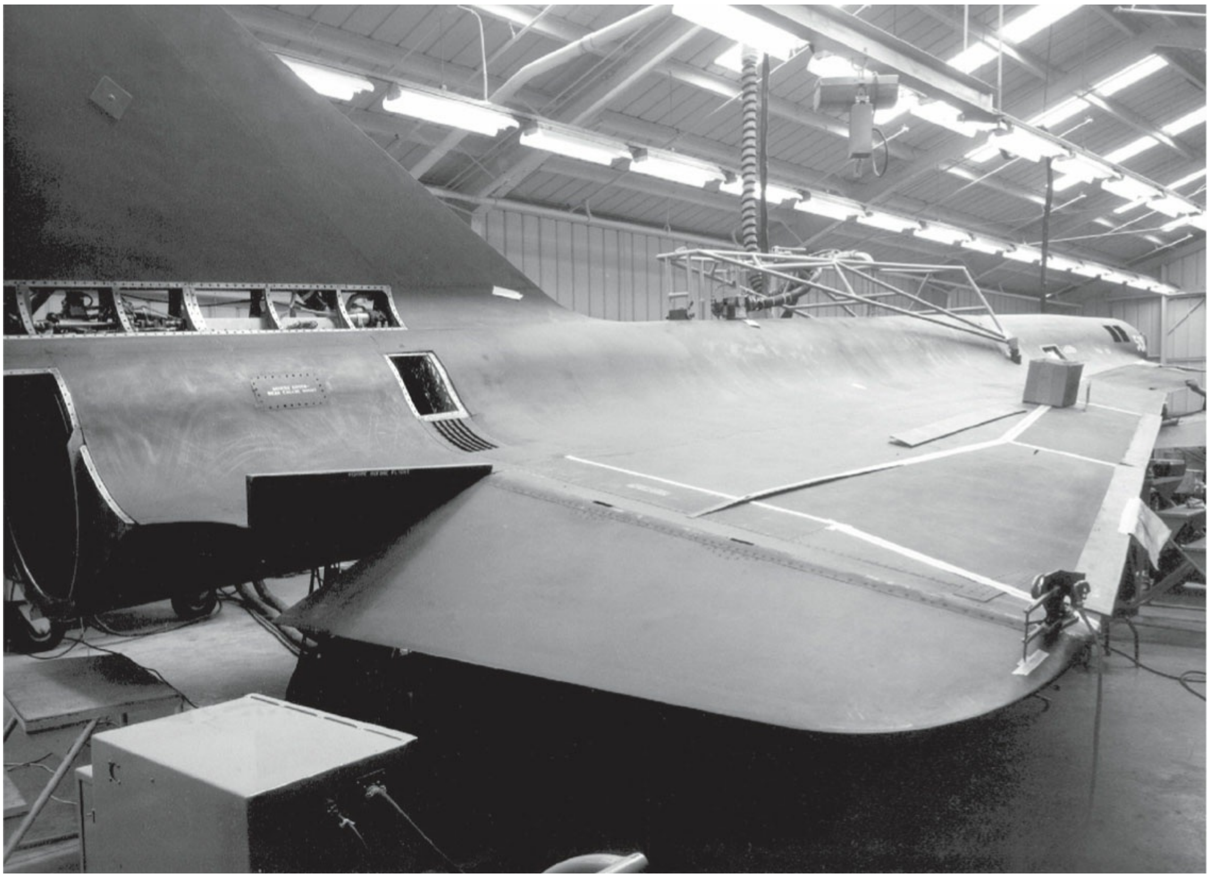
The D-21's rotating work fixture at the production and modification center at the Burbank location. (Author's collection)



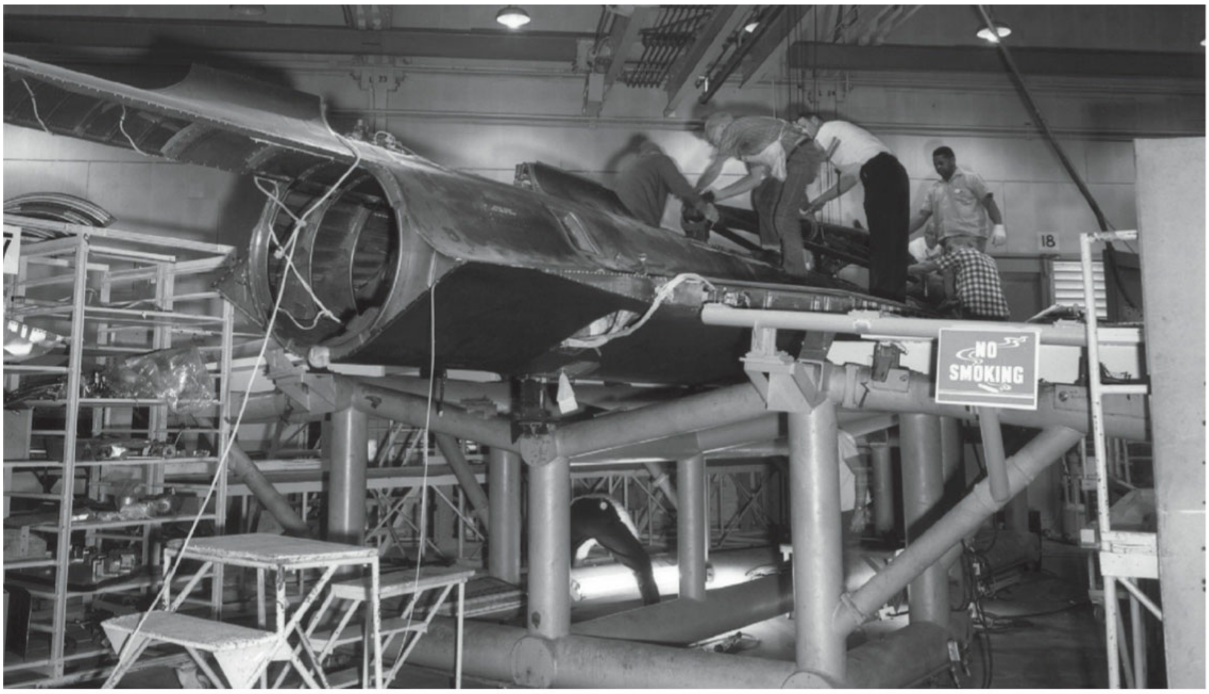
Another view of the D-21's rotating work fixture at the production and modification center at Lockheed's Burbank location. (Author's collection)


LATCH DRIVE SOCKET -2 PLACES - FITS STD 1/2" SOCKET WRENCH HANDLE
A
LOCK PIN (REF)
HATCH LATCH DRIVE ACCESS COVER
MAGAZINE COVER
SHUTTER
CARRIAGE
MAGAZINE
VIBRATION MOUNTS
COUNTERROTATING MASS
MIRROR
VIBRATION MOUNT
OBLIQUE HEAD

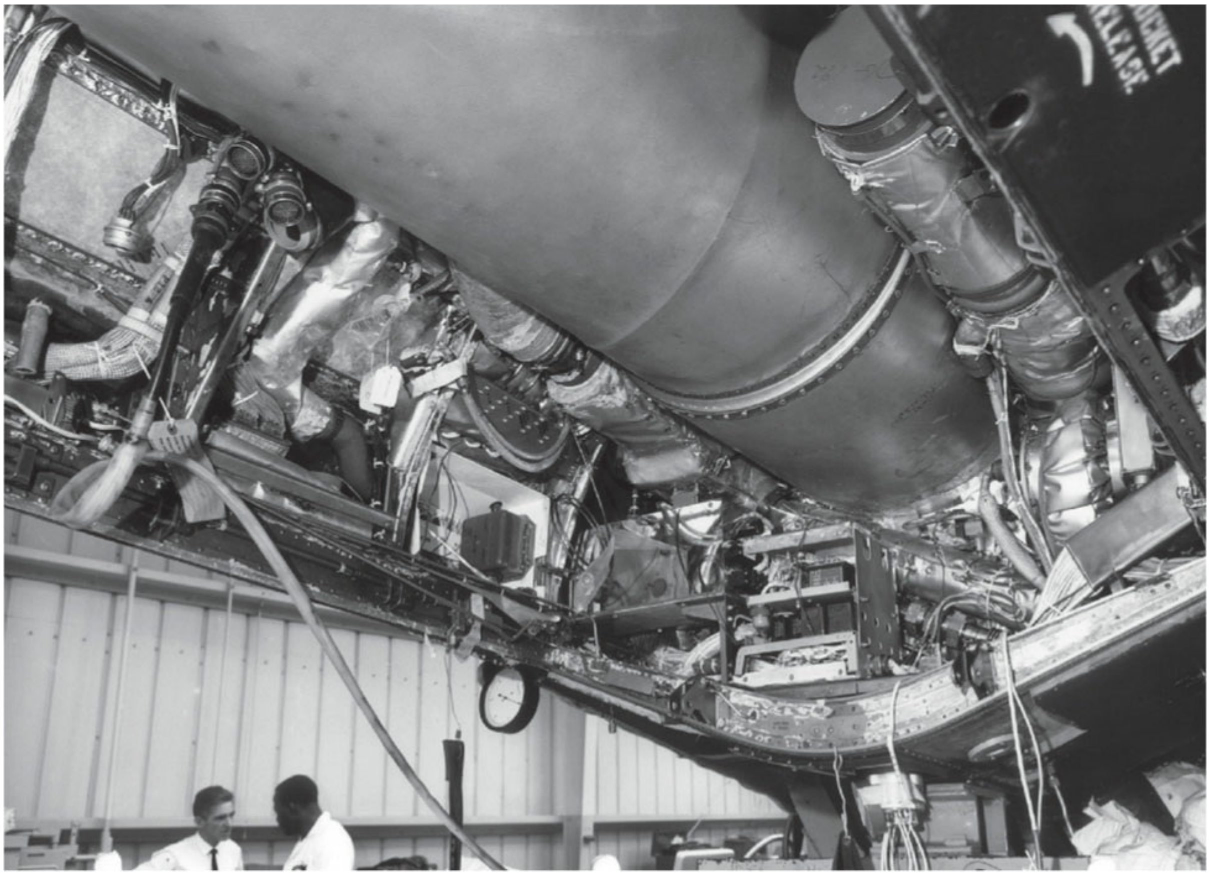
D-21 technical order illustrations showing camera loading, and drawings of the camera and the camera pallet installation. (Author's collection)



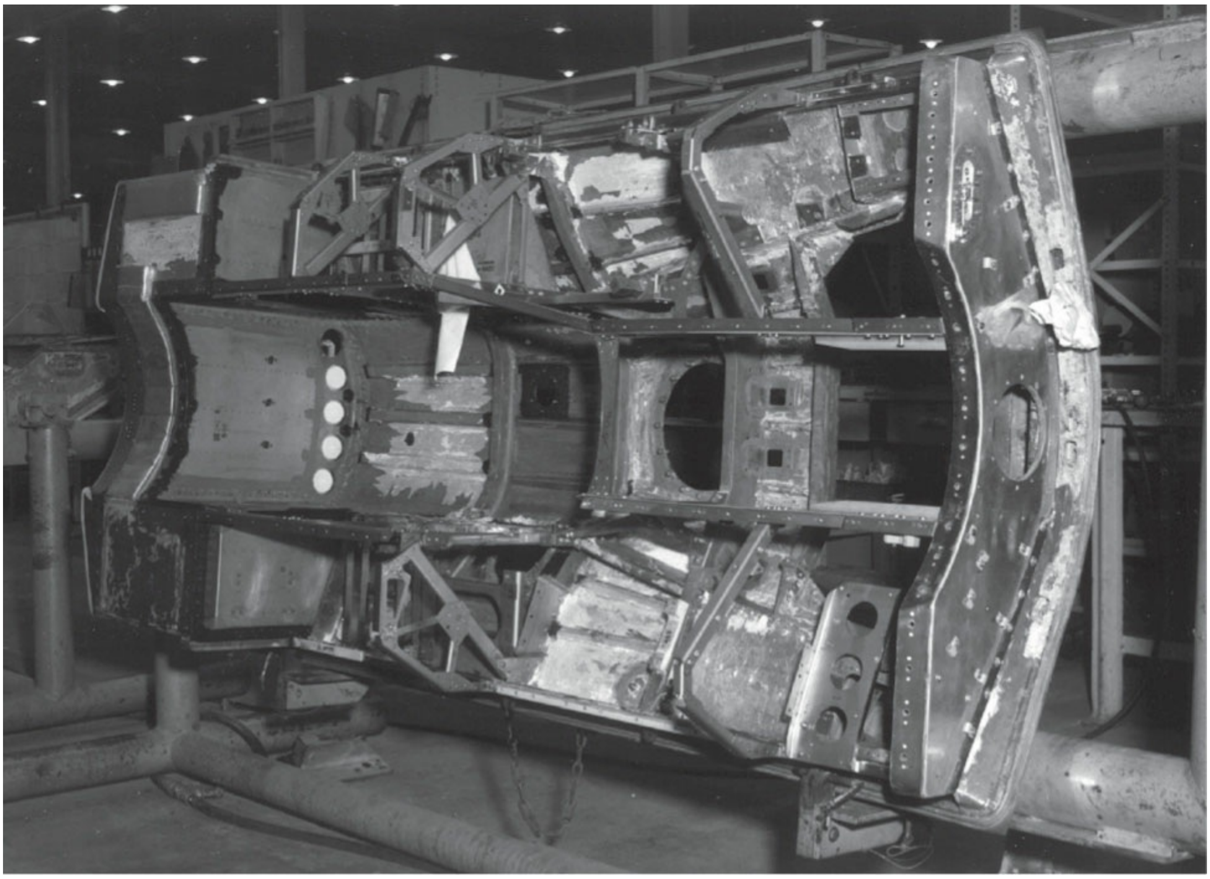
The D-21B modification bay at the Skunk Works Burbank facility. (Author's collection)



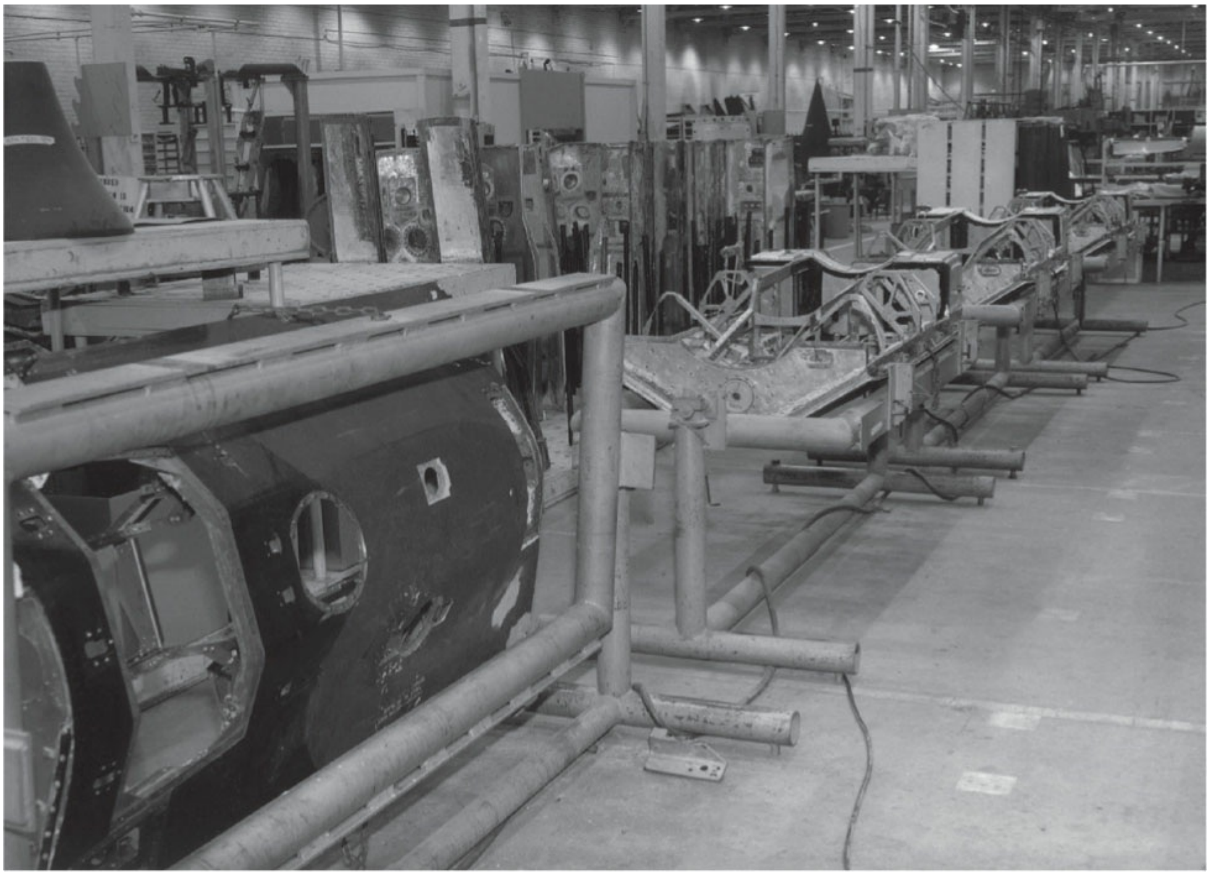
D-21B modifications at the Lockheed Skunk Works, Building 82. (Author's collection)



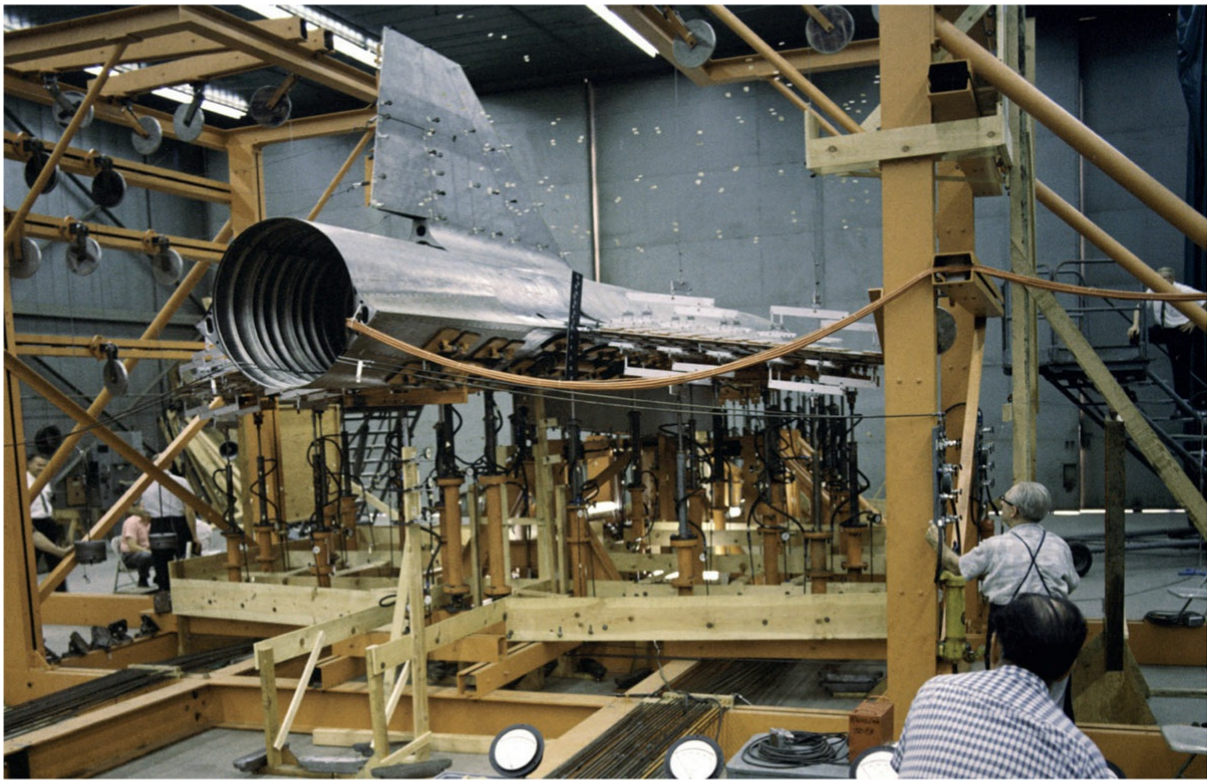
There is not much room in the reconnaissance bay of the D-21 for the pallet and associated equipment and camera. (Author's collection)

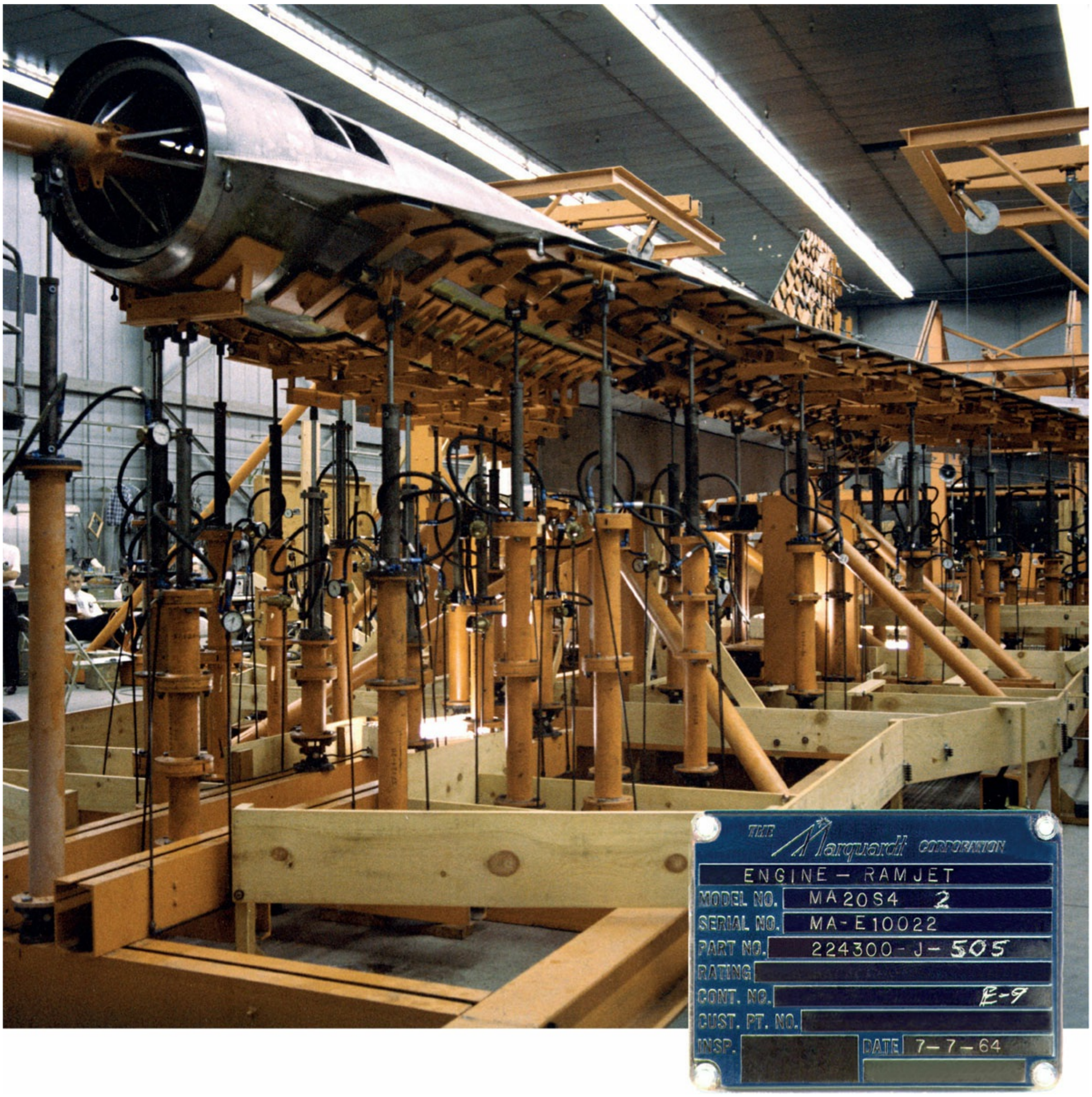


This is the reconnaissance pallet used on the D-21. As with the entire D-21, all of the structure of the pallet and airframe is titanium. (Author's collection)



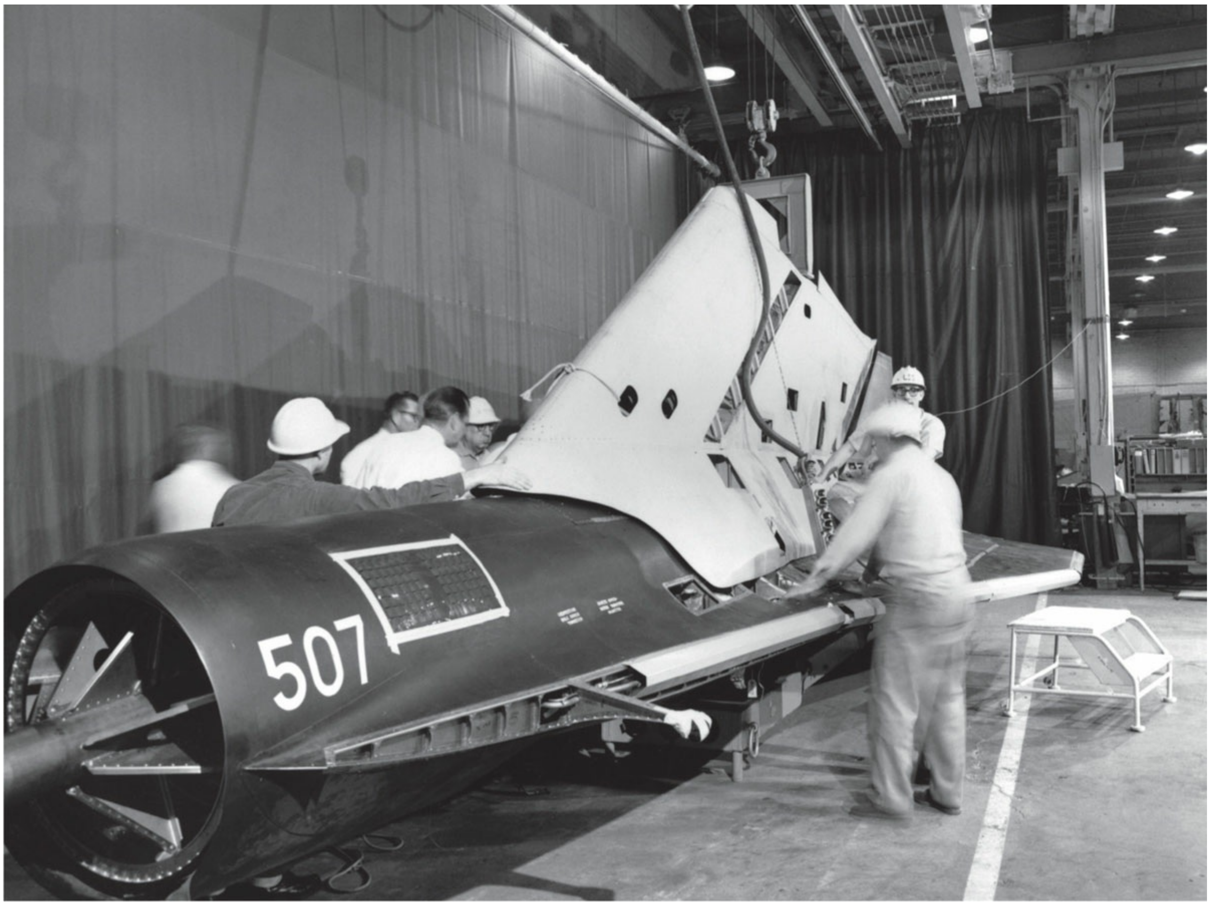
These D-21 pallets are all lined up and ready for installation of the inertial navigation system (INS) package, the autopilot and HR-3325D camera. (Author's collection)

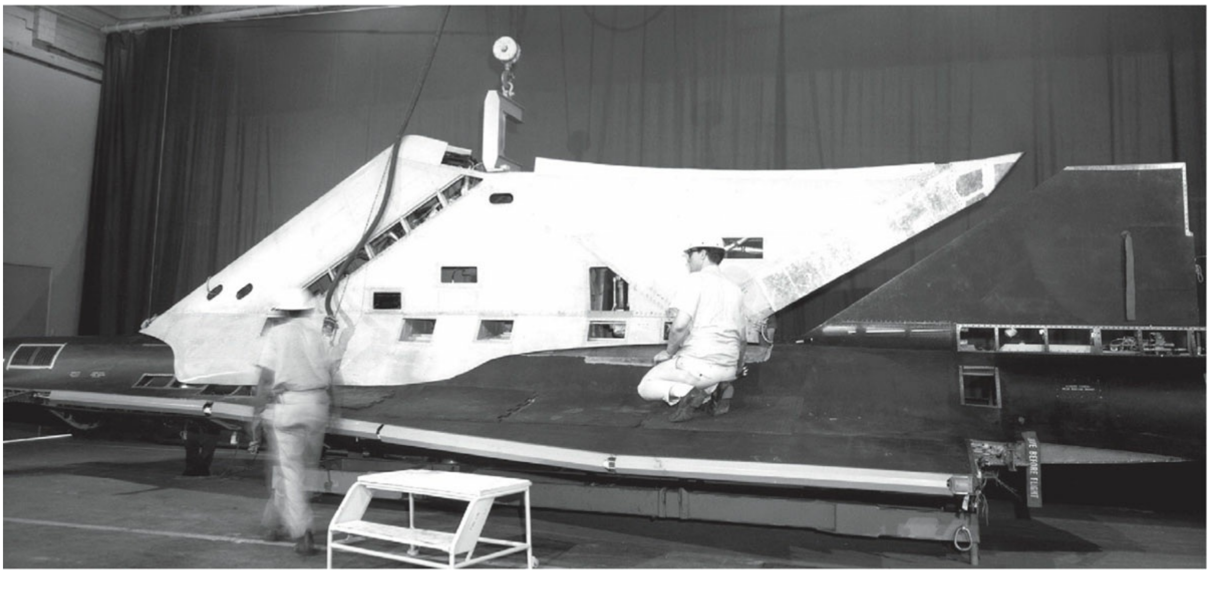




THE Marquardt CORPORATION
ENGINE — RAMJET
MODEL NO. MA 20S4 2
SERIAL NO. MA-E10022
PART NO. 224300-J-505
RATING
CONT. NO. E-9
CUST. PT. NO.
INSP.
DATE 7-7-64

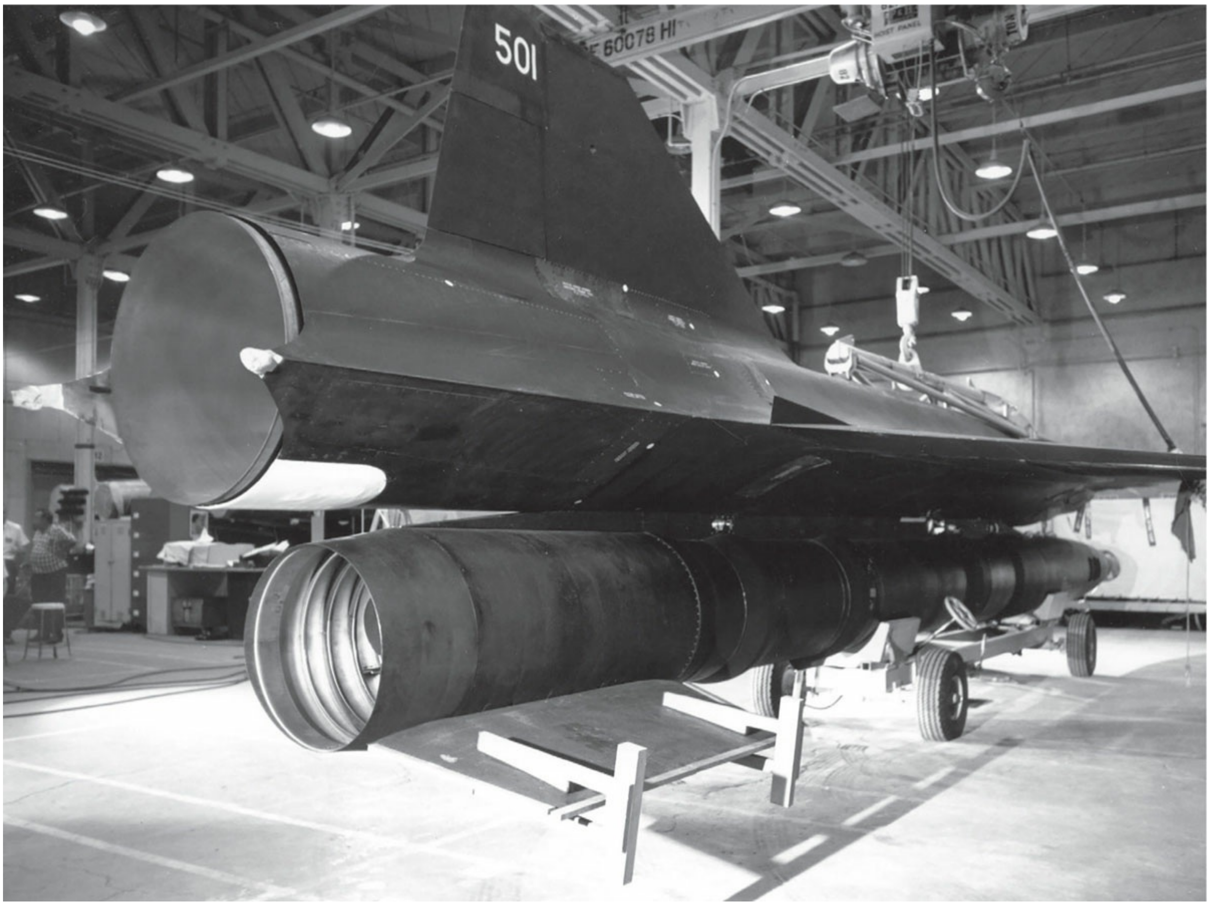
Before any aircraft or drone can be flown, it must be tested to its maximum in both flexing and bending as a result of high-speed flight and loads encountered during operational and flight test missions. (Lockheed Martin)



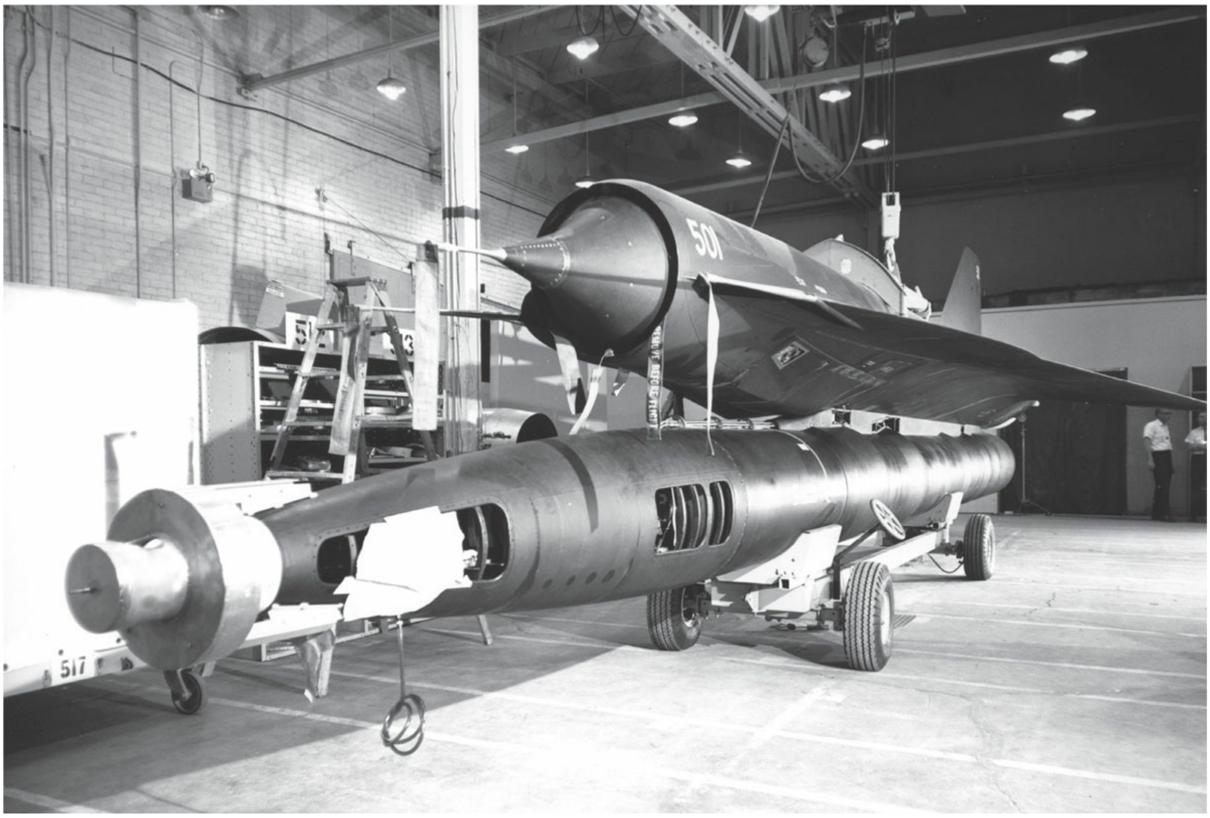


The very first mating of D-21B 507 to the launch pylon at the Skunk Works on 1 June 1967. (Author's collection)

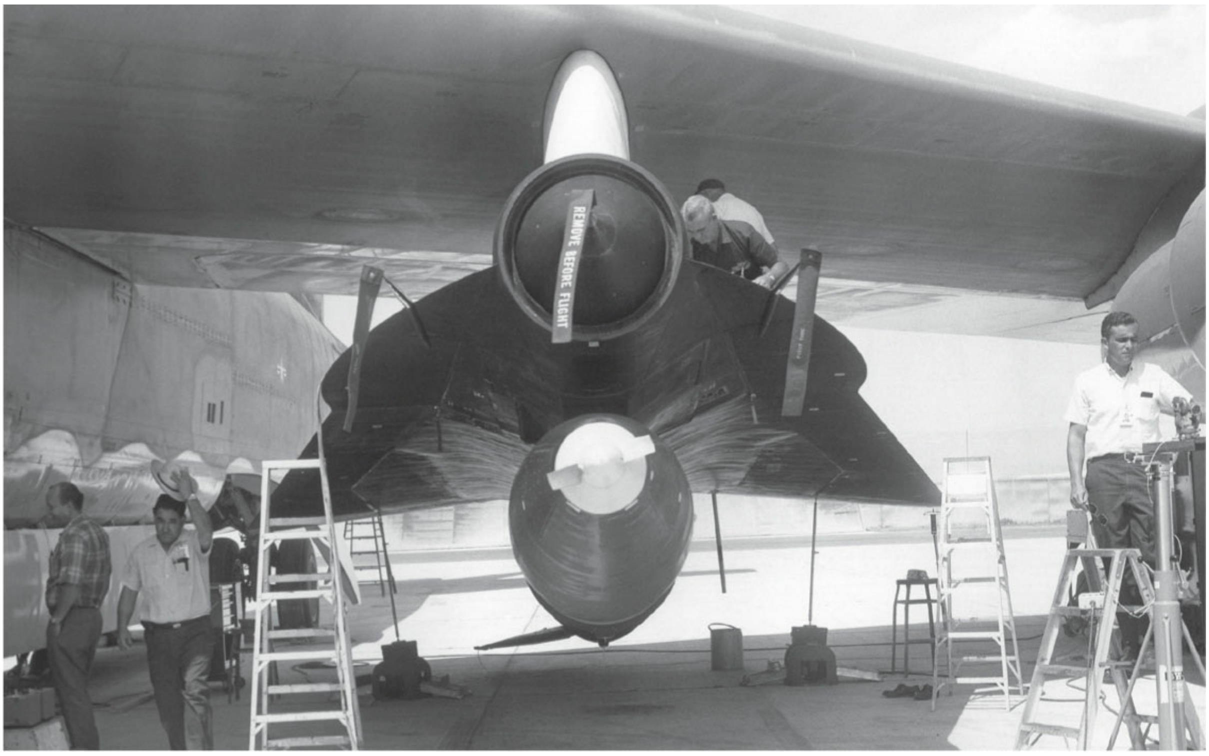
501
BE 60079 HI



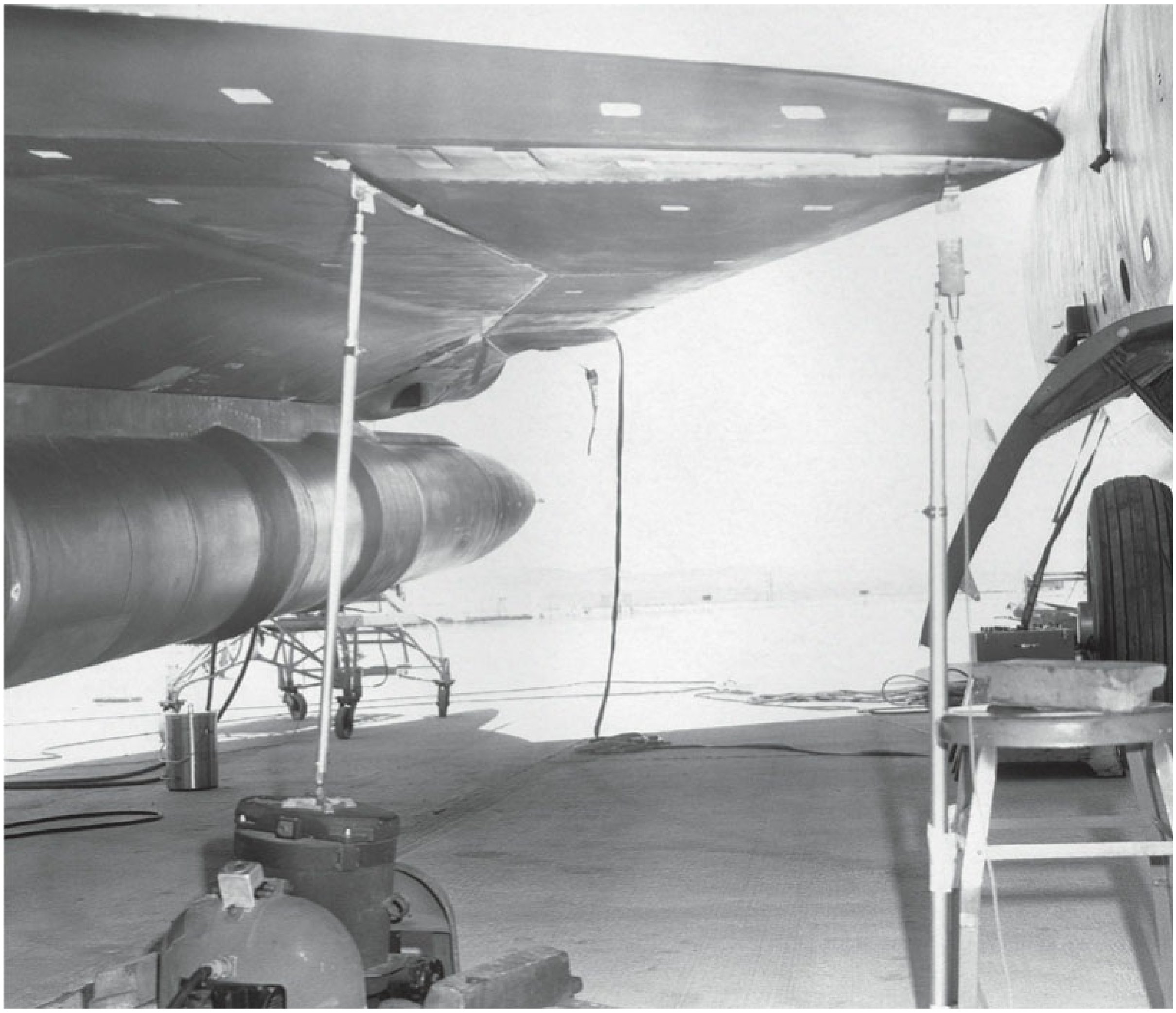
The ramjet-powered D-21 drone was developed as a high-speed, unmanned strategic reconnaissance platform. Originally designed to be air-launched from atop specially equipped A-12s, designated M-21, it was later modified for underwing carriage and rocket-assisted launch from the Boeing B-52H. (Lockheed Martin)



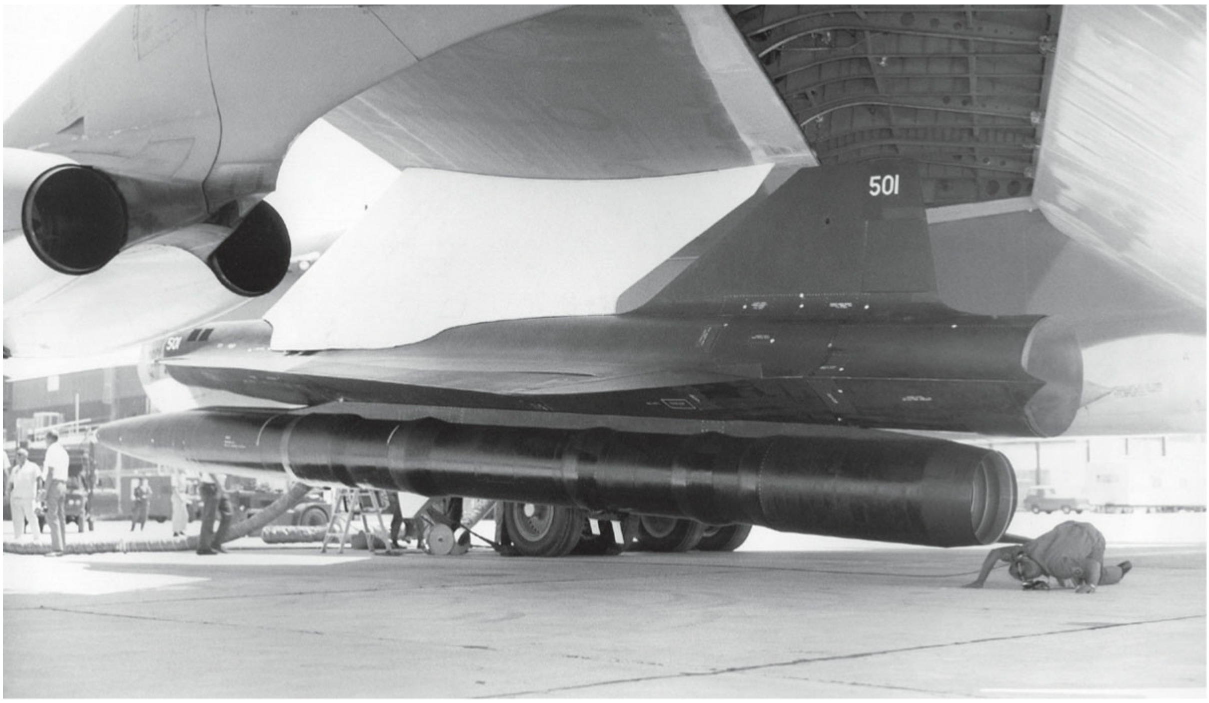
A nose-on view of the A-92 booster attached to D-21B 501. Lockheed used D-21B 501 and 507 as "Pathfinders" to ensure all systems worked as designed. (Author's collection)


REMOVE BEFORE FLIGHT

The very first loading of a D-21B on 11 July 1967 with inert booster to the Lockheed-developed and -built launch pylon at the main hangar complex at Area 51. (Author's collection)

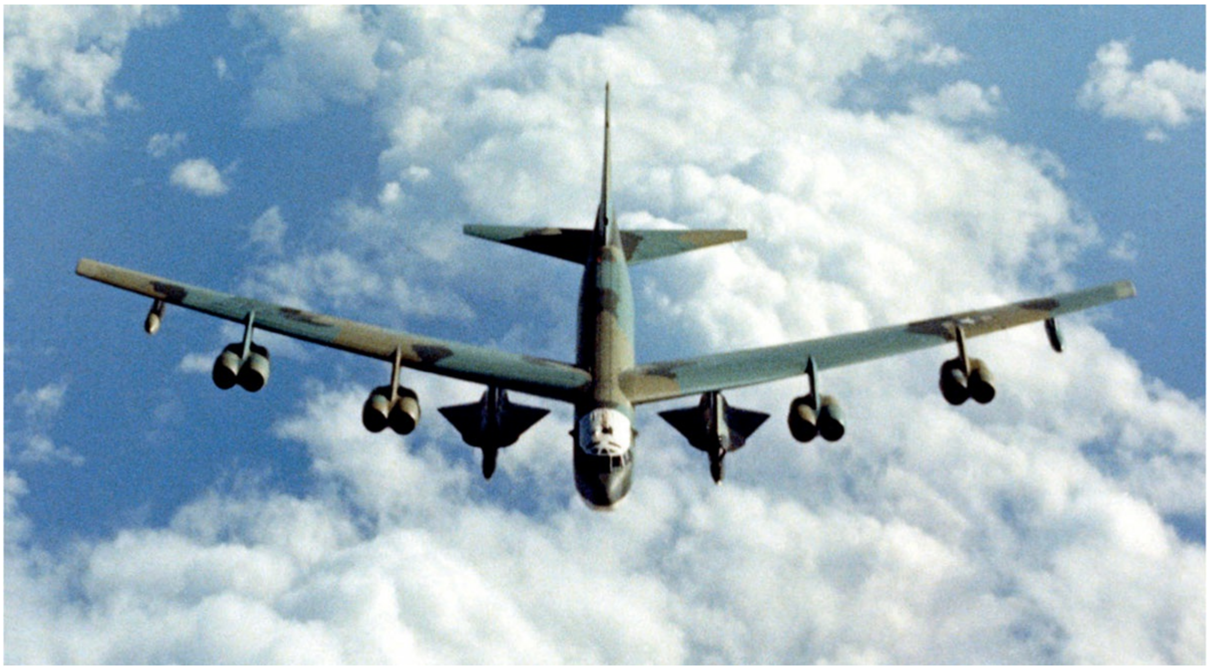


To test the design integrity of the A-92 booster, the D-21B pylon-attach points and the overall effectiveness of the installation, a series of "Shakers" are attached to the D-21B at several locations. If something was on incorrectly, or if something was loose, the "Shakers" would sort it out. (Author's collection)

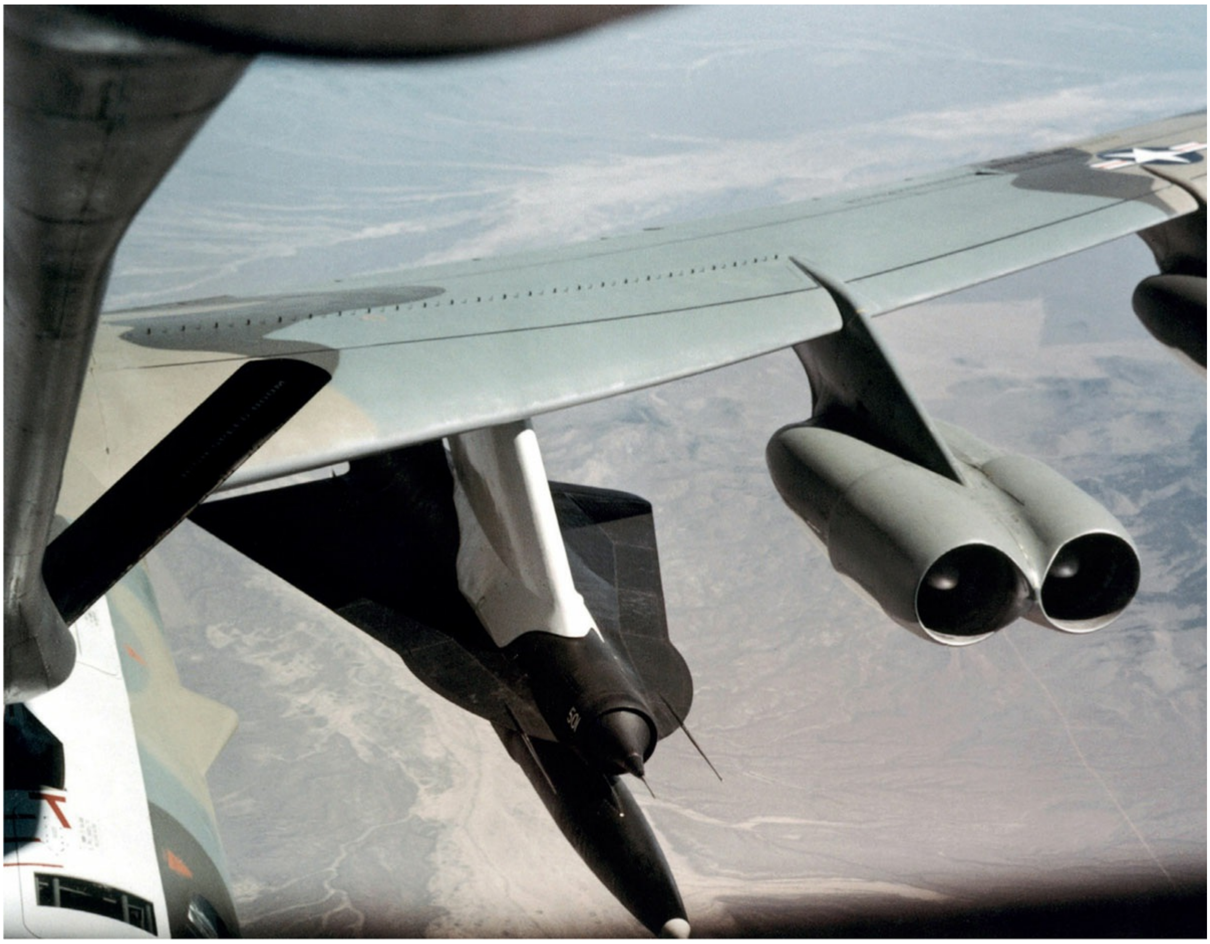


On 27 July 1967, an Air Force NCO assigned to "A" Flight of the 4200th Support Squadron looks to see if the booster has adequate ground clearance prior to its very first captive flight-test. (Author's collection)

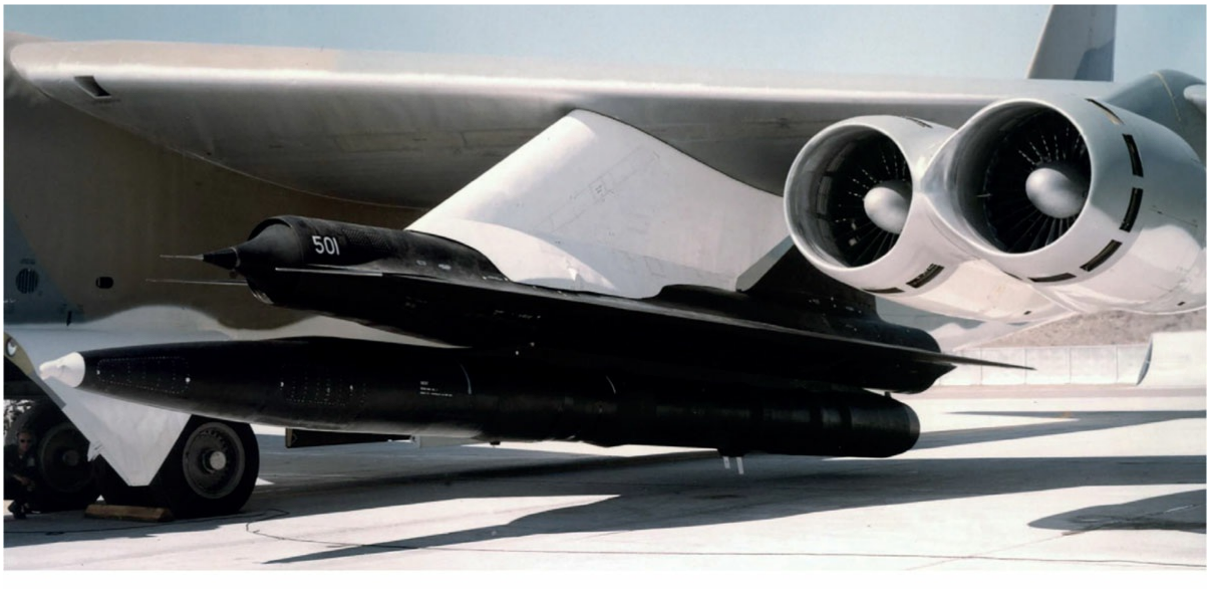
On the ramp at the north end of Area 51, B-52H 61-0021 going through a preflight test for a "Captain Hook" test flight on 2 December 1967. (Lockheed Martin)



Senior Bowl Boeing B-52H 61-0021, with two D-21s, 501 and 504, as seen from the boom operators' station in a KC-135A Boeing Stratotanker. (Lockheed Martin)

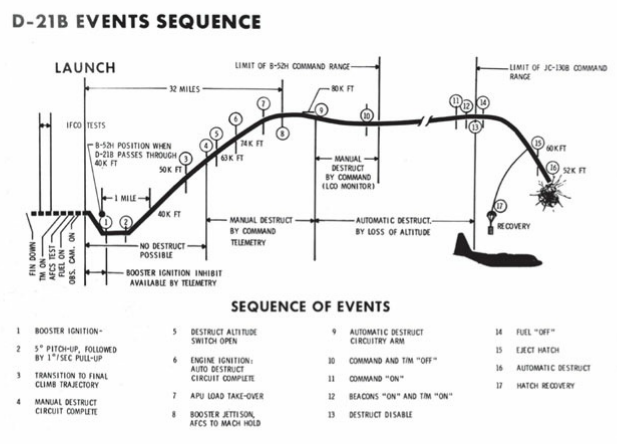


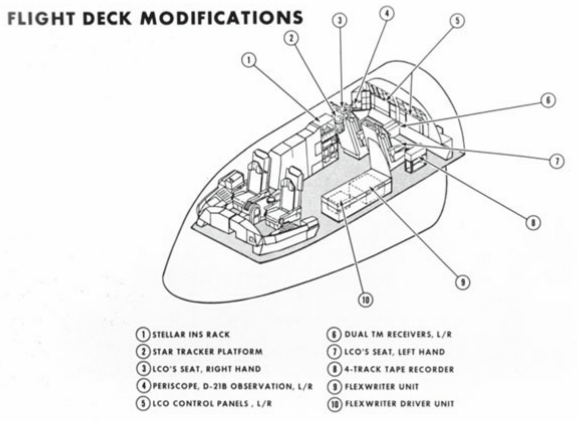
Senior Bowl Boeing B-52H 61-0021, lining up for a hookup to a KC-135A during a "Captain Hook" test launch of D-21B 512 on 16 June 1968. (Lockheed Martin)

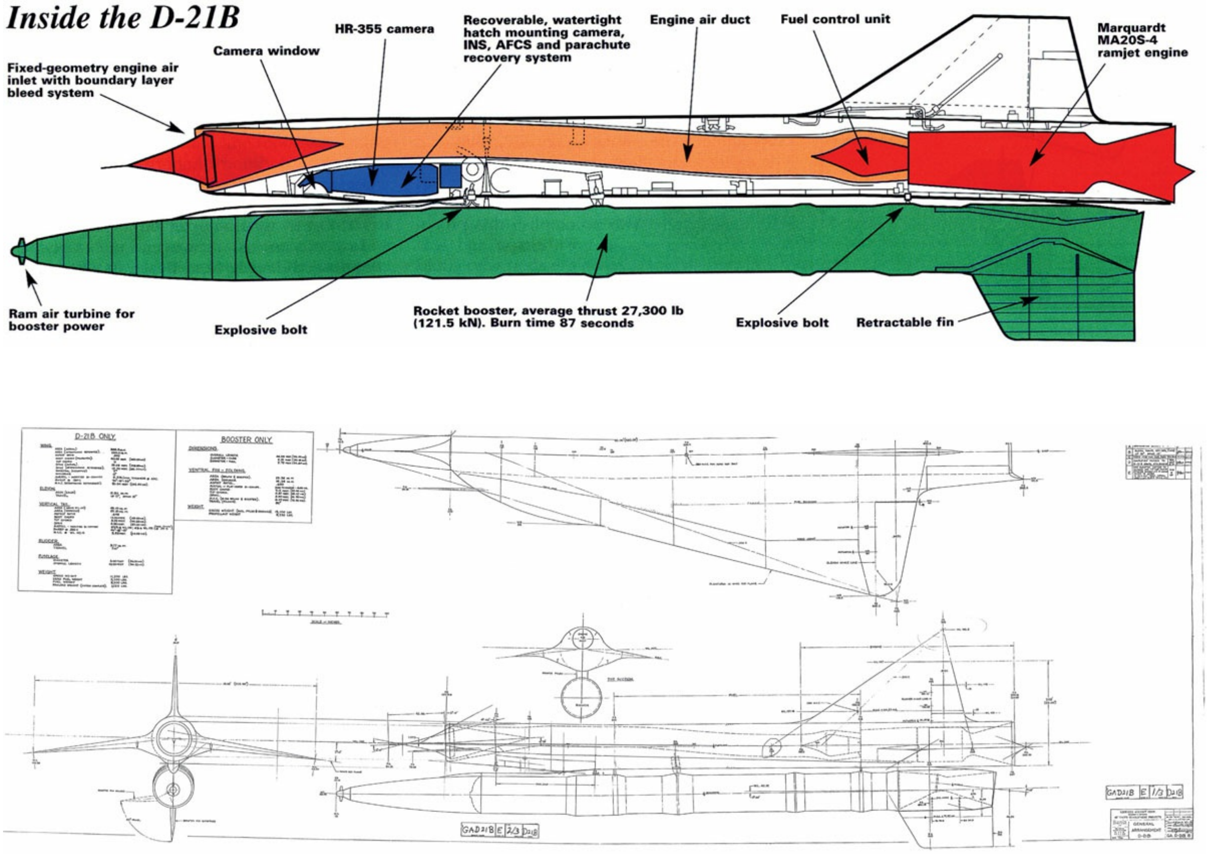


A closeup view of the D-21B 501 with booster attached to the Senior Bowl B-52H, 61-0021, on 11 August 1967. (Lockheed Martin)

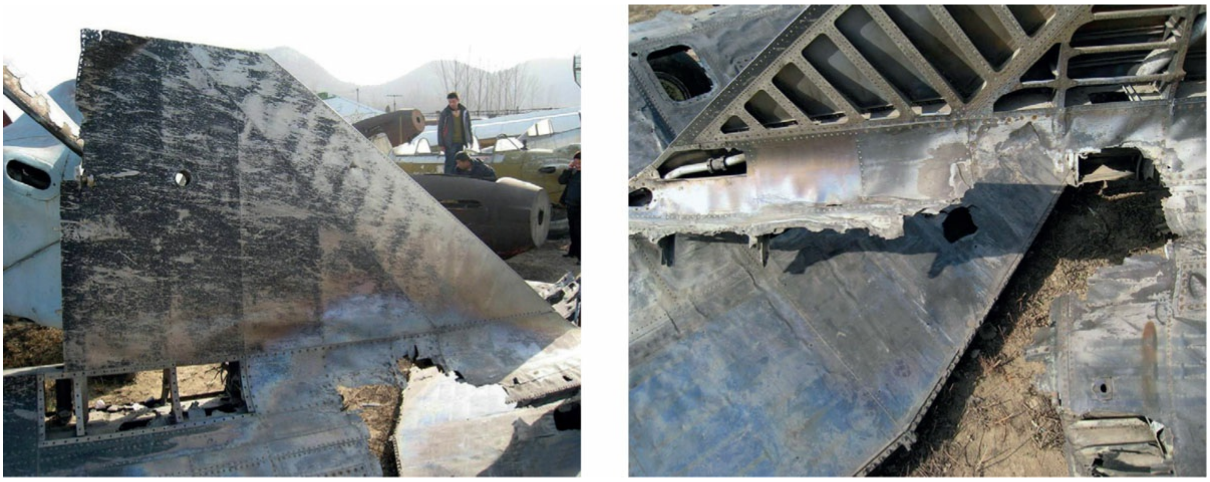
Bottom view of the Senior Bowl B-52H carrying two D-21s during a test flight in the summer of 1967. (Lockheed Martin)


D-21B EVENTS SEQUENCE
LAUNCH
LIMIT OF B-52H COMMAND RANGE
LIMIT OF JC-130B COMMAND RANGE
32 MILES
80K FT
IFCO TESTS
B-52H POSITION WHEN D-21B PASSES THROUGH 40K FT
74K FT
63K FT
50K FT
40K FT
1 MILE
60K FT
52K FT
MANUAL DESTRUCT BY COMMAND (LCO MONITOR)
MANUAL DESTRUCT BY COMMAND TELEMETRY
AUTOMATIC DESTRUCT, BY LOSS OF ALTITUDE
RECOVERY
NO DESTRUCT POSSIBLE
BOOSTER IGNITION INHIBIT AVAILABLE BY TELEMETRY
FIN DOWN
TM ON
AFCS TEST
FUEL ON
OBS. CAM. ON
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
SEQUENCE OF EVENTS
1 BOOSTER IGNITION-
2 5° PITCH-UP, FOLLOWED BY 1°/SEC PULL-UP
3 TRANSITION TO FINAL CLIMB TRAJECTORY
4 MANUAL DESTRUCT CIRCUIT COMPLETE
5 DESTRUCT ALTITUDE SWITCH OPEN
6 ENGINE IGNITION: AUTO DESTRUCT CIRCUIT COMPLETE
7 APU LOAD TAKE-OVER
8 BOOSTER JETTISON, AFCS TO MACH HOLD
9 AUTOMATIC DESTRUCT CIRCUITRY ARM
10 COMMAND AND T/M "OFF"
11 COMMAND "ON"
12 BEACONS "ON" AND T/M "ON"
13 DESTRUCT DISABLE
14 FUEL "OFF"
15 EJECT HATCH
16 AUTOMATIC DESTRUCT
17 HATCH RECOVERY


FLIGHT DECK MODIFICATIONS
1
2
3
4
5
6
7
8
9
10
① STELLAR INS RACK
② STAR TRACKER PLATFORM
③ LCO'S SEAT, RIGHT HAND
④ PERISCOPE, D-21B OBSERVATION, L/R
⑤ LCO CONTROL PANELS , L/R
⑥ DUAL TM RECEIVERS, L/R
⑦ LCO'S SEAT, LEFT HAND
⑧ 4-TRACK TAPE RECORDER
⑨ FLEXWRITER UNIT
⑩ FLEXWRITER DRIVER UNIT

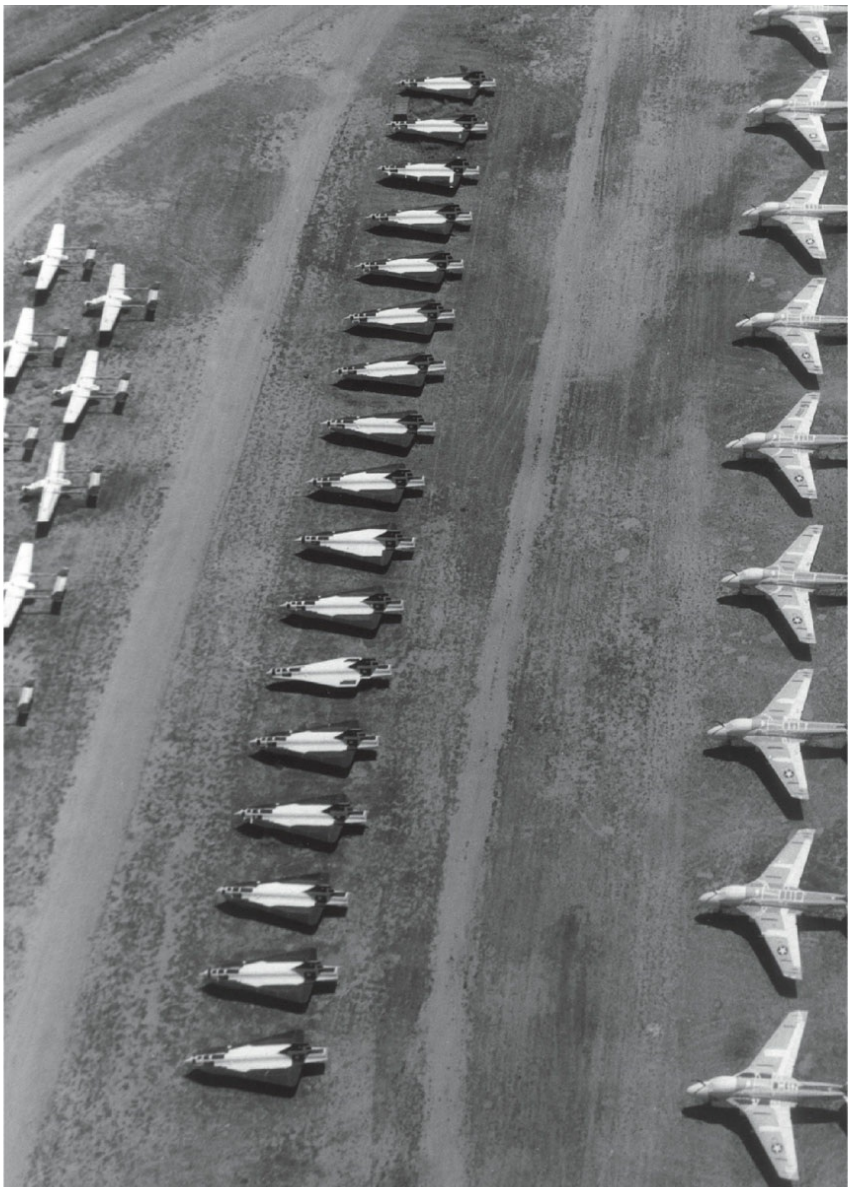

Inside the D-21B
Fixed-geometry engine air inlet with boundary layer bleed system
Camera window
HR-355 camera
Recoverable, watertight hatch mounting camera, INS, AFCS and parachute recovery system
Engine air duct
Fuel control unit
Marquardt MA20S-4 ramjet engine
Ram air turbine for booster power
Explosive bolt
Rocket booster, average thrust 27,300 lb (121.5 kN). Burn time 87 seconds
Explosive bolt
Retractable fin
D-21B ONLY
BOOSTER ONLY
GAD21B E 1/3 D21B
GAD21B E 2/3 D21B

Illustrations for the D-21B. (Lockheed Martin)



What was left of D-21B 527, which crashed on its very last flight over mainland China. It is believed that the D-21B flamed out and was hit by a SA-2 surface-to-air missile as it fell below 45,000ft. Launched from B-52H on 20 March 1971, D-21B 527 had flown 2,935nm. This was its fourth and last operational mission; its camera was not recovered. The wreckage was salvaged and put on display at the China Aviation Museum. After the crash, the D-21B program closed down. (Author's collection)

The last day of Senior Bowl at Beale AFB, 23 July 1971. During its operational lifetime, Senior Bowl was one of the best-kept secrets in the military. During that time, "A"-Flight and the 4200th Support Squadron launched 16 D-21B vehicles from the B-52H, both in training and operational sorties. Only a very few select personnel were cleared for the project. Each member was cleared to Top Secret and then in addition required a Special Access Required (SAR) clearance. This unique level of clearance was (and still is) classified information. All Senior Bowl personnel had to be cleared to the same level, regardless of rank or grade. When the program began, everyone involved had to sign all kinds of security paperwork (jokingly referred to as "burn before reading" material) promising, in effect, that they would never mention the term D-21B nor discuss the Senior Bowl program with anyone not equally cleared. (Author's collection)



On 23 July 1971 the end came for the 4200th Support Squadron and Senior Bowl. The remaining 17 D-21Bs were first moved from Area 51 to Norton AFB, and then, starting in 1977, transported under very tight security to their final home, the "Bone Yard," better known as MASDC, at Davis Monthan AFB. These 17 D-21Bs are what remained of the original 38 D-21A/Bs. (Author's collection)

Three D-21s at NASA Dryden, Edwards AFB. (Author's collection)

A D-21 at Beale AFB, Marysville, CA. (James C. Goodall)

A D-21 at Davis Monthan AFB at AMARG. (James C. Goodall)

M-21 TAGBOARD

1964

PROGRAM: M-21

Name: Tagboard

Mission: Drone launch mother aircraft

Length: 102ft 3in (31.17m)

Wing Span: 55ft 7in (16.94m)

Height: 18ft 5in (5.61m)

Max T.O. Weight: 117,000lb (53,000kg)

First Flight: 22 December 1964

Last Flight: 30 July 1966

Crew: 2

Number Built: 2

Power Plant: 1 x Pratt & Whitney J58 (JT11D-20)

Design Speed: Mach 3.24 (2,150mph; 3,460km/h)

Service Ceiling: 80,000ft (24,000m)

Combat Radius: Unlimited with in-flight refueling

Weapons Load: D-21 11,000lb (5,000kg) bombs

During the development of the M-21 program, the D-21 Tagboard program was being developed as a separate, and highly classified compartmentalized program with no linkage to the manned Blackbirds, such as the M-21. On 20 March 1963, Lockheed was given an official CIA letter of contract for the D-21. (At this early date, the D-21 was still being referred to as the Q-12; that designation was later changed.) The contract gave Lockheed responsibility for the navigation systems, the ramjet and the airframe.

The D-21 was the heart of this program and was designed as an extremely high-speed, high-altitude reconnaissance vehicle – in a sense, a much smaller, unmanned version of the A-12 but with similar capabilities. It was considered to be a "one way aircraft," meaning that each D-21 would make one flight only and then self-destruct. While still in the design stages, two Lockheed A-12s were modified to carry the D-21 on a top-mounted dorsal pylon located on the rear centerline between the engines and the vertical stabilizers. A second cockpit was installed for the D-21 Launch Control Officer (LCO) in the area of the A-12's "Q-bay." The Q-bay was already pressurized and refrigerated, making the modification relatively easy.

By now, the somewhat unusual M-21 designation had been assigned to the dedicated and purpose-built carrier A-12s, of which there were to be two. The "M" stood simply for "Mother." At the same time, it was decided to rename the Q-12 to the D-21, thus making it the "Daughter" aircraft. The numerals "1" and "2" of A-12 and Q-12, etc., were reversed so as not to confuse the "Mother/Daughter" combination with other "-12" variants.

On 31 December 1963, Johnson noted that wind tunnel and paper studies were leading him to believe there would be launching difficulties with the M-21 "Mother" ship. According to Johnson: "Going through the fuselage shock wave is very hard. I am insisting on launching at full power, but there are problems regarding fuel-air ratio to the engine and engine blow-out in this condition."

A month later he wrote: "Reviewed launch conditions again, and was very upset by recent tunnel tests which show we must make a pushover to launch. This is due to making the pylon too short. This was done for structural reasons, but got us into aerodynamic troubles which weren't recognized at once, although I suspected that we might encounter such troubles when it was done."

Concurrent with the D-21 work, the purpose building of two M-21s to serve as launch platforms was underway at Burbank. A single, dorsally mounted, low-drag pylon had been developed that was sufficiently strong to support the 11,000lb D-21 at Mach 3. The pylon contained a primary support post with locking hook, a secondary lock, provisions for emergency pneumatic jettison of the D-21, and a refueling line that was used to cool the D-21 and top off the D-21's tanks prior to launch. D-21 separation was to be accomplished by flying the drone off the M-21 during a slight (approximately 0.9g) pushover maneuver. The D-21 was not forcibly ejected from the M21.

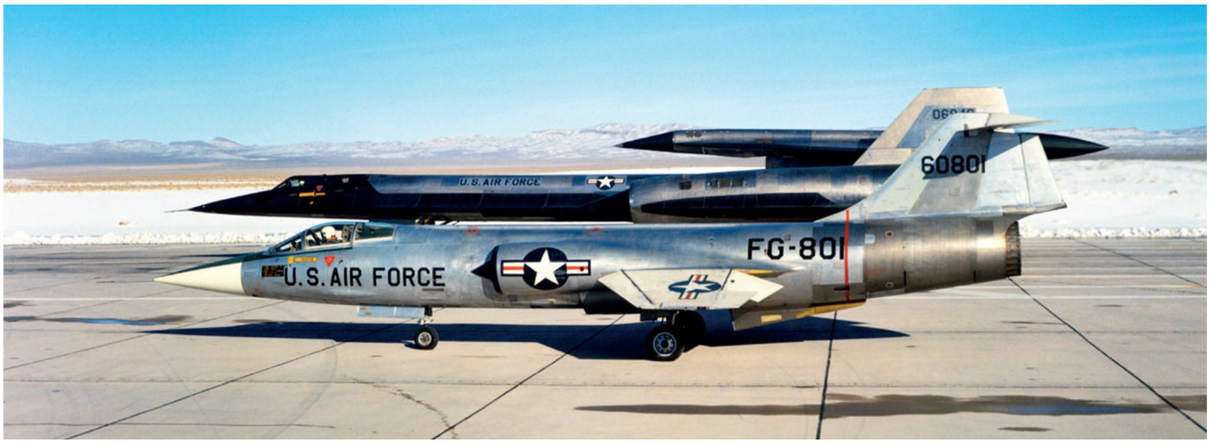
A fit check using M-21 134 and D-21 501 was completed successfully on 19 June 1964 in Building 309/310 at the Skunk Works. Few problems surfaced during the mating. On 12 August 1964, it was delivered to Groom Lake to undergo initial flight-testing.

On 22 December 1964, the first flight of the M/D-21 was successfully completed from Area 51. It flew well and, in spite of having low-powered engines, went supersonic on the first flight. Interestingly, on this same day, the first SR-71A successfully completed its first flight from Lockheed's facility at Palmdale, California.

At this point, the Tagboard program was unfortunately progressing rather slowly overall. By mid-May 1965, Lockheed had the M/D-21 up to Mach 2.6 but not up to launch speeds. Between May and 21 October 1965, Johnson decided to put the newer 34,000lb-thrust Pratt & Whitney J58 Model K engines into 135 and changed from the Hamilton Standard inlet control system to one designed by Johnson's crew.

A team from the test site received the okay from the highest authorities to proceed via a C-130 to Lockheed's SR-71 Assembly Facility at Air Force Plant 42, Site II, Palmdale. Its task was to secure the first three Model K J58s; the only three Model Ks in the inventory. These were to be used to power the Tagboard up to launch speed.

On 5 March 1966, the team finally saw light at the end of the tunnel and actually launched a D-21 from the back of the "Mother" bird. It was a great success, at least in terms of the launch. The exercise demonstrated that Lockheed had developed a successful launch technique. Johnson was quoted as saying: "This was the most dangerous maneuver we have ever been involved in, in any airplane I have ever worked on." In this groundbreaking mission, Bill Park, the Skunk Works' chief test pilot, was at the helm and Keith Beswick was the LCO.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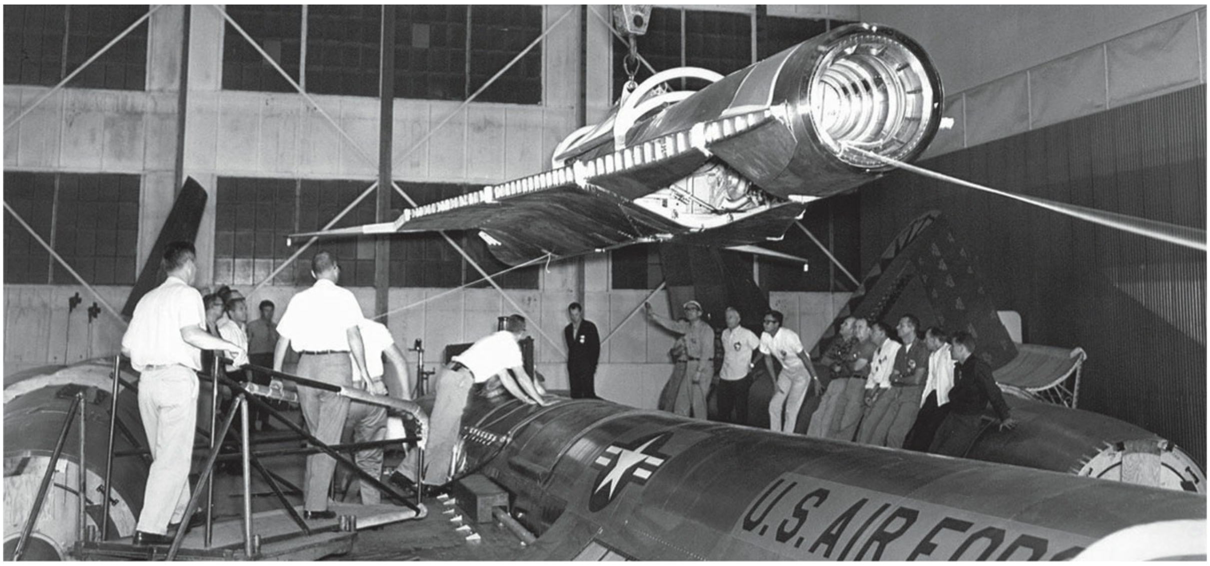
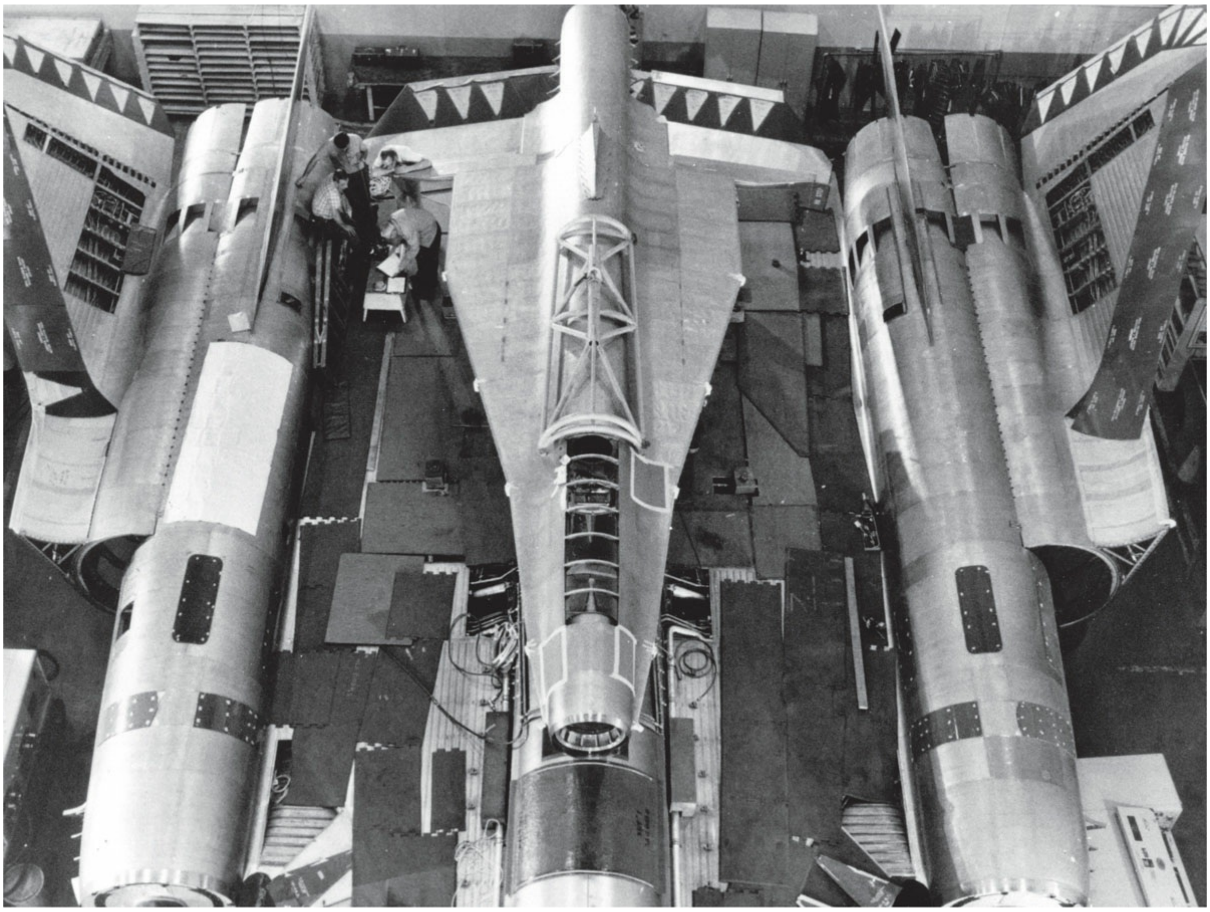
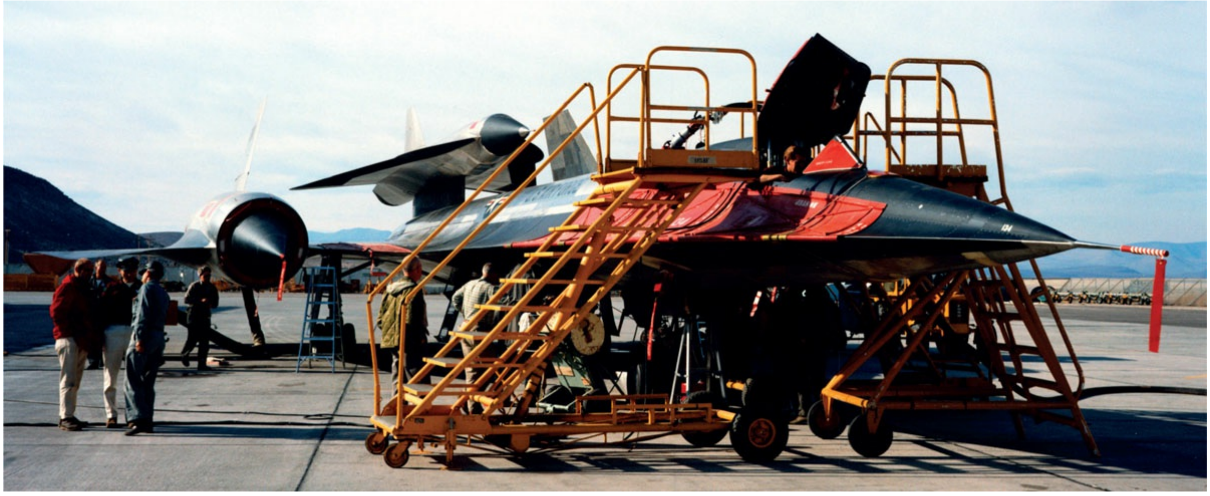
A great view from the left-hand side of the M/D-21 and F-104G 56-0801, the chase plane, on the ramp of Area 51. Note the frangible nose and tail cone on the D-21 Tagboard. This arrangement was only used during early flight-testing of the Tagboard D-21. (Lockheed Martin)



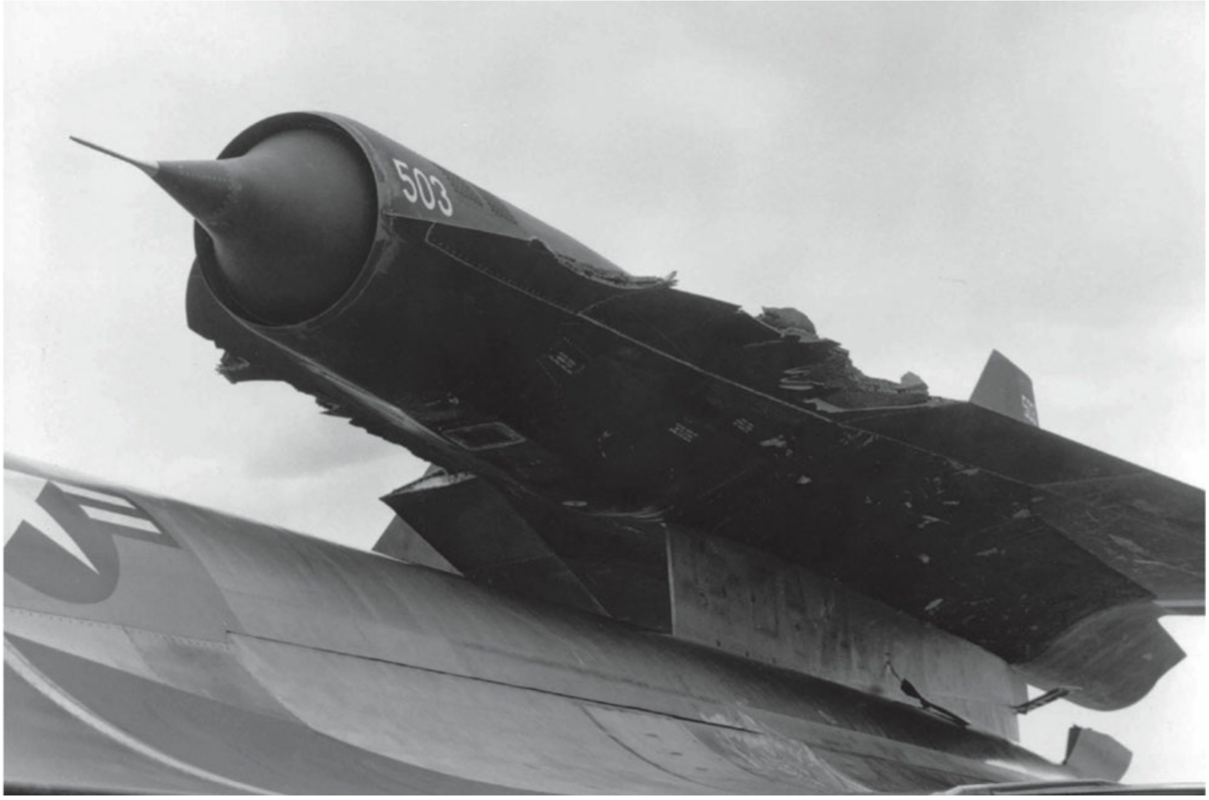
First test fit for the D-21 on the M-21 mother Blackbird. (Lockheed Martin)



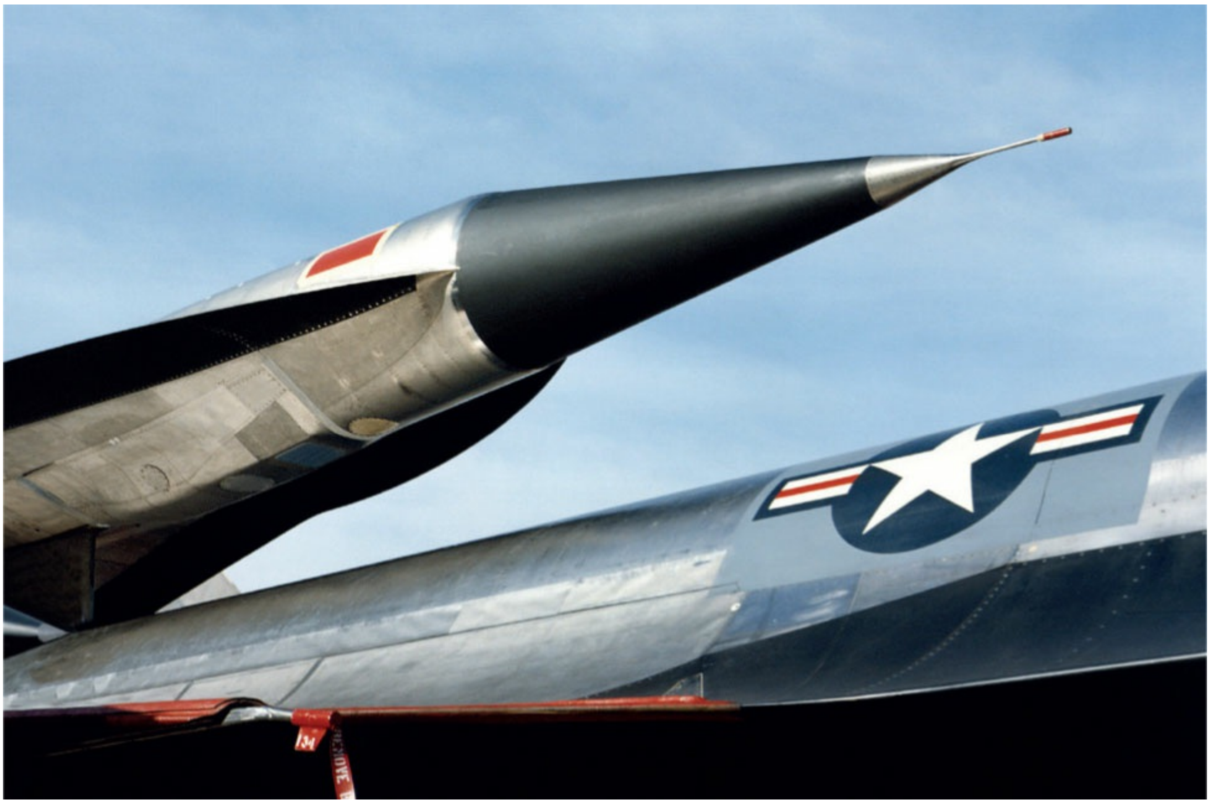
This was taken at Area 51 in Hangar 3. The M-21, 60-6940/134, which was natural metal with the composite panels and crew area painted with the "Red Spot Paint and Varnish"Iron Ball paint used on all Blackbirds. (Lockheed Martin)



Tagboard M/D-21 60-6940/134, as Lockheed personnel prep the M/D-21 for its very first flight on 22 December, 1964. (Lockheed Martin)



The D-21 503, showing the results of a problem with the frangible nose/inlet cone ejection, the result of which was extreme damage to the D-21's composite chine panels. (Lockheed Martin)



A detailed view of the D-21 nose cone used during early flight-test of the Tagboard M/D-21. (Lockheed Martin)

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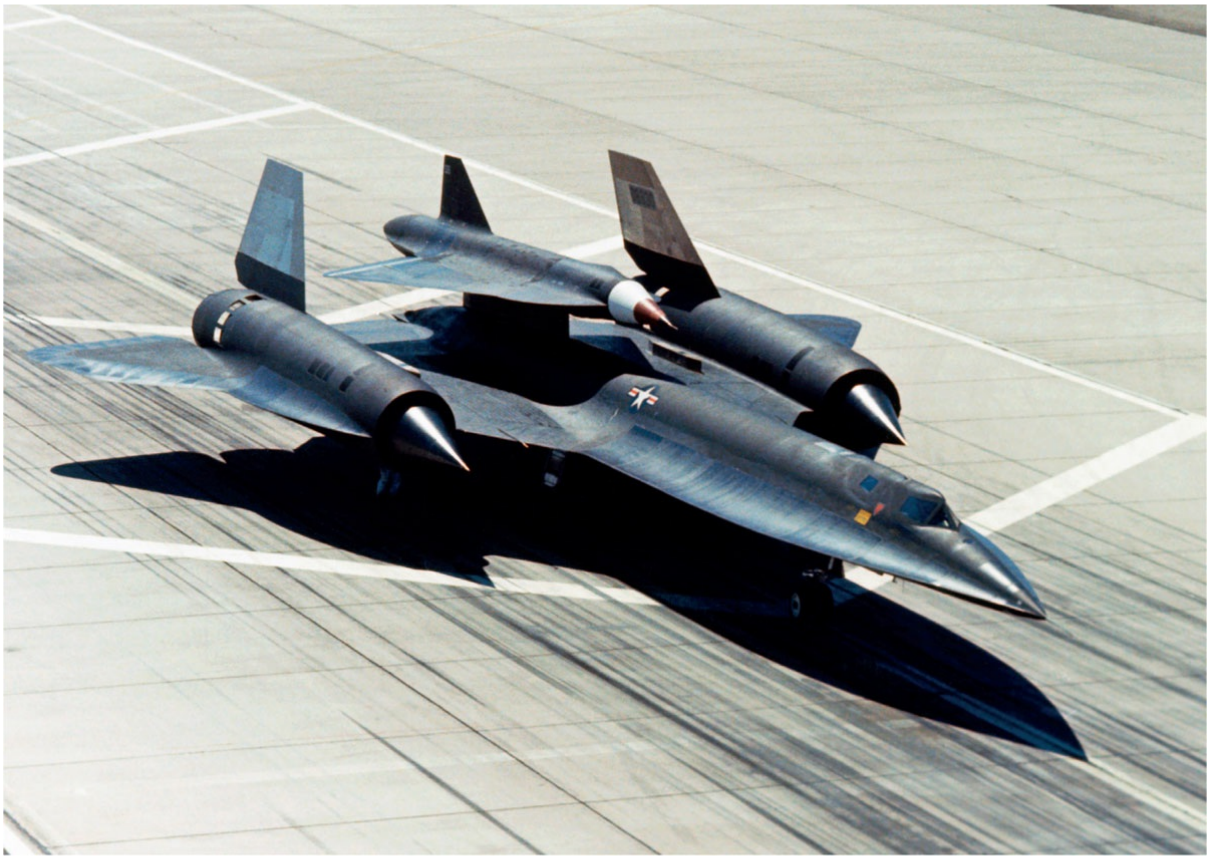
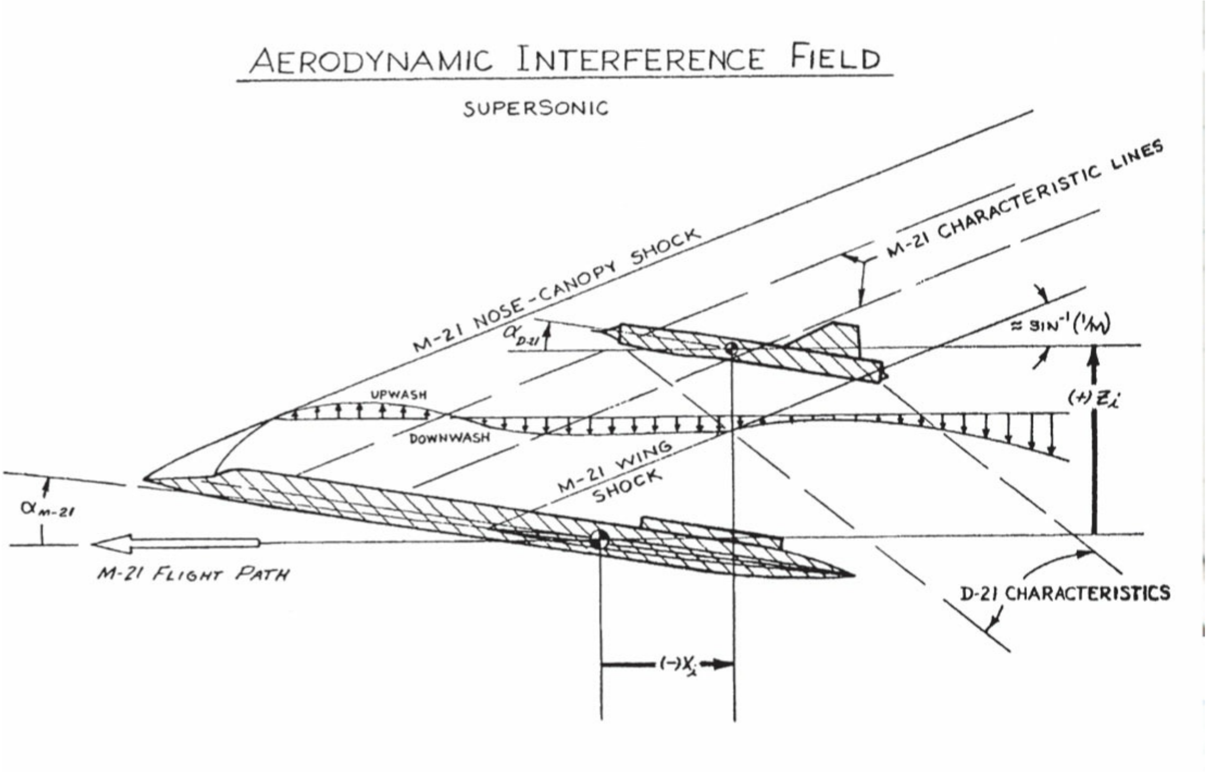
It's hard not to like the beautiful aircraft that came out of Kelly's Skunk Works. Here is the first flight of the M/D-21 with Lockheed chief test pilot, Bill Park in the M-21 and Lockheed test pilot Art Peterson flying chase on the F-104G. (Author's collection)

Lockheed GTD-21B

A 1/48th scale model of the D-21B with a stand that the author, Jim Goodall, made and presented to Ben Rich in the mid-1970s. (Lockheed Martin)



M-21 60-6941/135's first flight was in mid-May 1965, with Lockheed's chief test pilot, Bill Park. Its total number of flights was 95; total flight hours, 152:46. On 30 July 1966, the M-21 was lost 200 miles west of Point Mugu, CA, during a failed launch of a D-21. (Lockheed Martin)


AERODYNAMIC INTERFERENCE FIELD
SUPERSONIC
M-21 CHARACTERISTIC LINES
M-21 NOSE-CANOPY SHOCK
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D-21 CHARACTERISTICS
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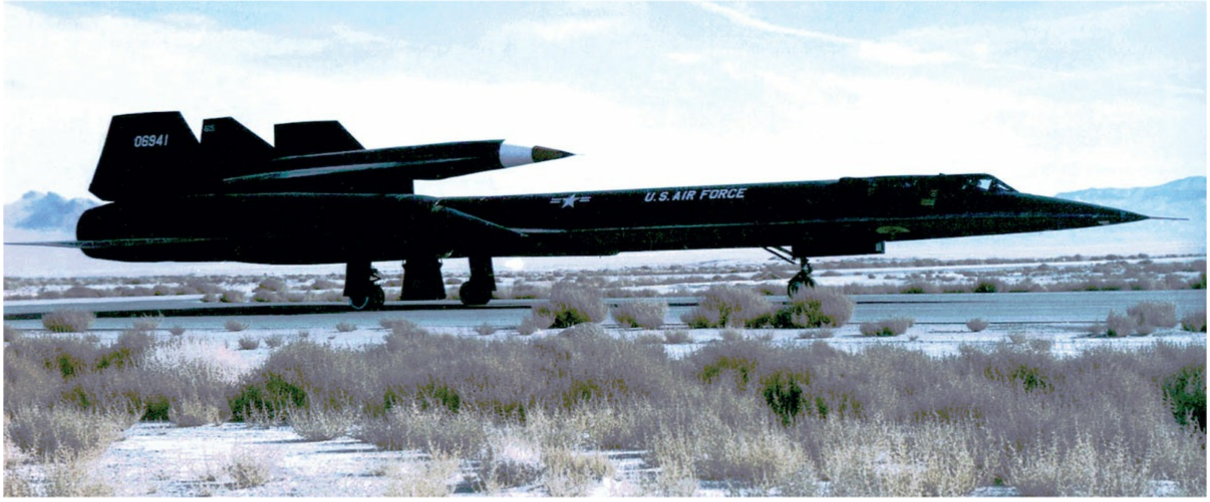
Engineering drawing on the separation dynamics of the M/D-21 in flight. (Author's collection)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The only other known photo of the second M/D-21, 60-6941/135, on the taxiway at Area 51 prior to its first captive test flight. (Author's collection)

SR-71A SENIOR CROWN

1964

PROGRAM: SR-71A

Name: Blackbird

Mission: Strategic reconnaissance

Length: 107ft 5in (32.74m)

Wing Span: 55ft 7in (16.94m)

Height: 18ft 6in (5.64m)

Max T.O. Weight: 152,000lb (68,946kg)

First Flight: 22 December 1964

Last Flight: 9 October 1999

Crew: 2

Number Built: 32

Power Plant: 2 x Pratt & Whitney J58 (JT11D-20)

Design Speed: Mach 3.24 (2,150mph; 3,460km/h)

Service Ceiling: 87,250ft (26,594m)

Combat Radius: Unlimited with in-flight refueling

Weapons Load: Various cameras, electronic countermeasures (ECM), Advanced Sythentic Aperture Radar (ASAR) and defensive (DEF) equipment

There is arguably no aircraft that has captured the imagination of the public quite like the SR-71 Blackbird. The Blackbird has been out of commission for a while, but there's not one person at an air show who wouldn't give something special to see one fly low to the ground overhead. There's a reason for this: the SR-71, in many respects, has yet to be beaten in many of the records it has broken, and it was built in a time when America was breaking barrier after barrier in terms of scientific endeavors. Believe it or not, the SR-71 Blackbird was first built by Lockheed Martin in the late 1950s. This is an old bird, but that hasn't stopped it from crashing multiple records for speed. It was such a fast, high-flying aircraft that even NASA wanted to take the Blackbird on to do testing of their own. With a service ceiling of 85,000ft, it could push up to the envelope of where the atmosphere ends and space begins.

Kelly Johnson had first mentioned working on a "reconnaissance/strike" variant of the A-12 for the Air Force during April 1962, though preliminary discussions relating to a configuration of this type had been ongoing almost from the beginning of the program during 1958 and 1959. During March 1962, the Air Force had been cleared to give Lockheed a study contract wherein the various Air Force mission options – including the ability to destroy ground targets – could be more precisely identified.

The new aircraft would differ from its predecessor in one major respect ... and several minor; it would be given a pressurized aft cockpit for a second crewmember in the Q-bay position normally occupied by sensor equipment. A slight fuselage stretch would result from adding another fuselage fuel tank, along with other changes in the way sensors were carried.

In the meantime, a shortage of thin titanium sheet brought to light the sensitivity of this aspect of the program. Titanium had, in fact, been a source of major concern for the Skunk Works from the very beginning. As it was far and away the single most important material utilized in the A-12 family, extraordinary means were used to control every facet of its manufacture and implementation. Johnson would summarize this in a paper written for *Lockheed Life* during December 1981: "The Skunk Works traditionally avoids the snarls of excess report writing. However, with titanium, for an outfit that hated paperwork, we really deluged ourselves with it. Having made 13 million titanium parts to date, we can trace the history of all but the first few back to the mill pour and, for about the last 10-million of them, even the direction of the grain in the sheet from which the part was cut has been recorded.”

All activity relating to the R-12 and RS-12 configurations had, of course, been kept completely under wraps in the Skunk Works and within the confines of the involved Air Force and CIA offices. On 24 July 1964, however, President Johnson publicly unveiled the existence of Lockheed’s latest 3 Mach-capable aircraft. The full content of Johnson’s speech was:

> I would like to announce the successful development of a major new strategic manned aircraft system, which will be employed by the Strategic Air Command. This system employs the new SR-71 aircraft, and provides a long range advanced strategic reconnaissance plane for military use, capable of worldwide reconnaissance for military operations. The Joint Chiefs of Staff, when reviewing the RS-70, emphasized the importance of the strategic reconnaissance mission. The SR-71 aircraft reconnaissance system is the most advanced in the world. The aircraft will fly at more than three times the speed of sound. It will operate at altitudes in excess of 80,000 feet. It will use the most advanced observation equipment of all kinds in the world. The aircraft will provide the strategic forces of the United States with an outstanding long-range reconnaissance capability.
>
> The system will be used during periods of military hostilities and in other situations in which the United States military forces may be confronting foreign military forces.
>
> The SR-71 uses the same J58 engine as the experimental interceptor previously announced, but it is substantially heavier and it has a longer range. The considerably heavier gross weight permits it to accommodate multiple reconnaissance sensors needed by the Strategic Air Command to accomplish their strategic reconnaissance mission in a military environment. This billion-dollar program was initiated in February of 1963. The first operational aircraft will begin flight testing in early 1965. Deployment of production units to the Strategic Air Command will begin shortly thereafter.

WARNING
THIS AIRCRAFT CONTAINS A SEAT
CONTAINING AN EXPLOSIVE CHARGE.
SEE MAINTENANCE MANUAL BEFORE
REMOVING
RESCU
CANOPY JETTISON
1.PUSH BUTTON TO OPEN

The man himself, Robert "Long Boy" Gilliland, the first man to fly the SR-71, sitting in the cockpit after the first historic flight on 22 December 1964. (Lockheed Martin)

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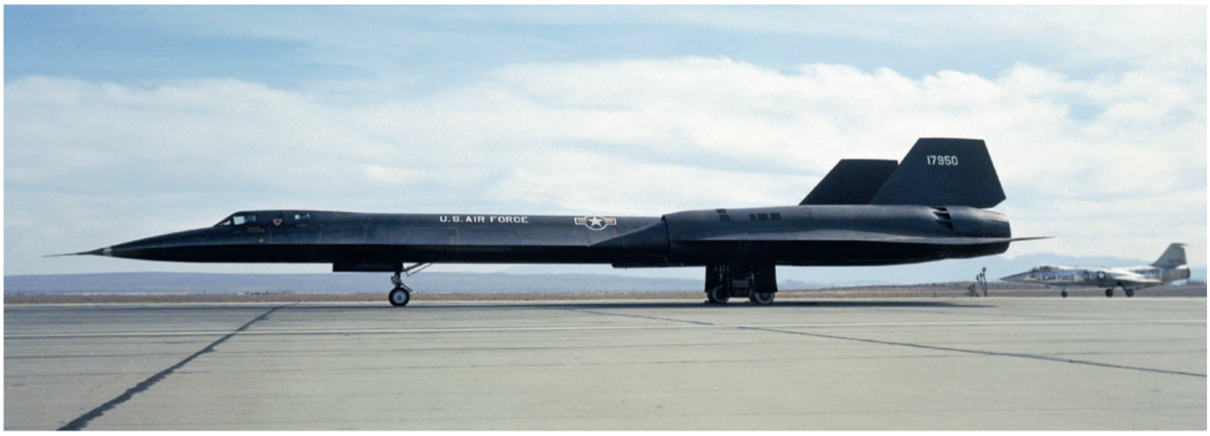
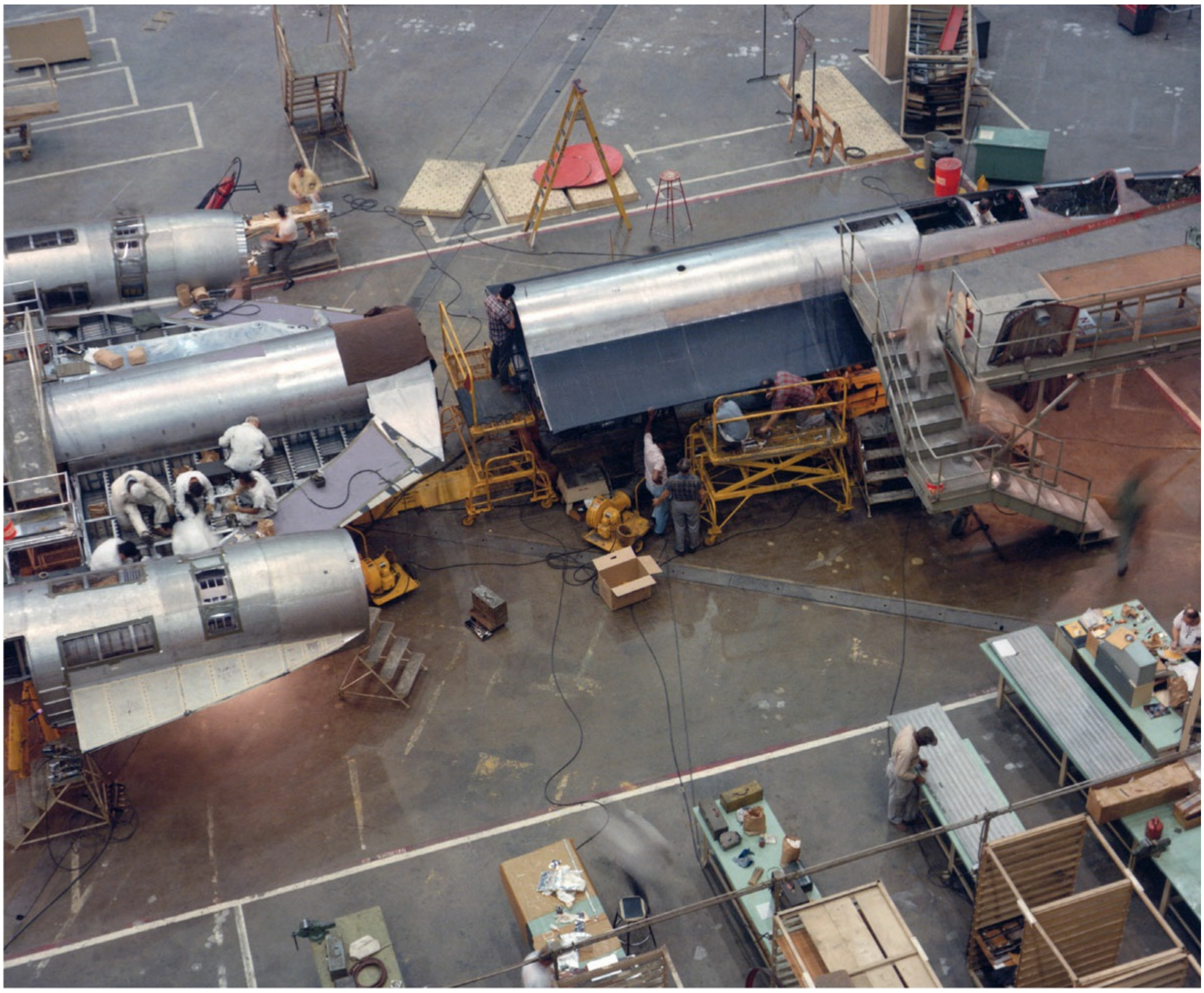
A look-down view on the SR-71's very first flight on 22 December 1964. (Lockheed Martin)

Standing in front of the number one SR-71A, Lockheed test pilot Bob Gilliland was the first person to fly the Air Force version of the Blackbird, the SR-71, on 22 December 1964. (Lockheed Martin)

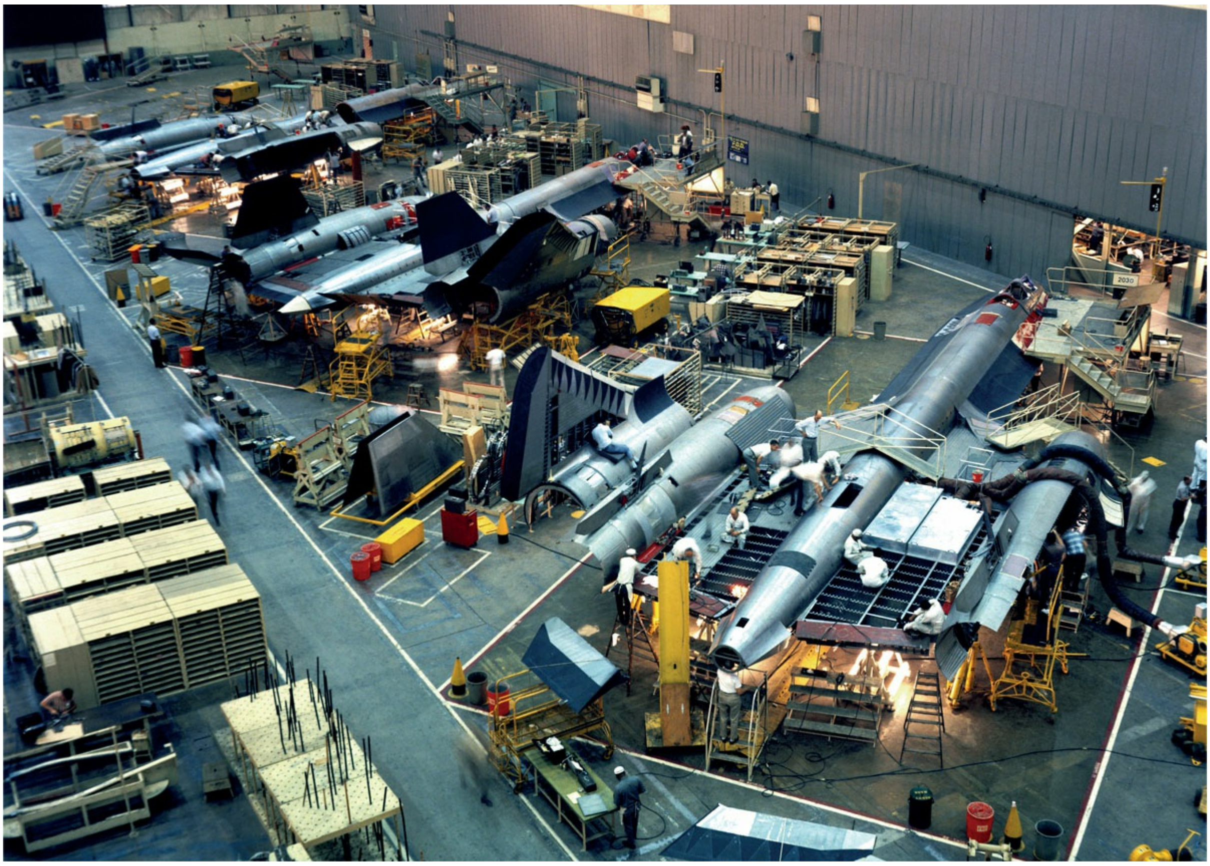


Another photo taken on the day of the SR-71's first flight. Behind the SR-71 is the F-104 chase aircraft to be flown by Lockheed test pilot Art Peterson. (Lockheed Martin)

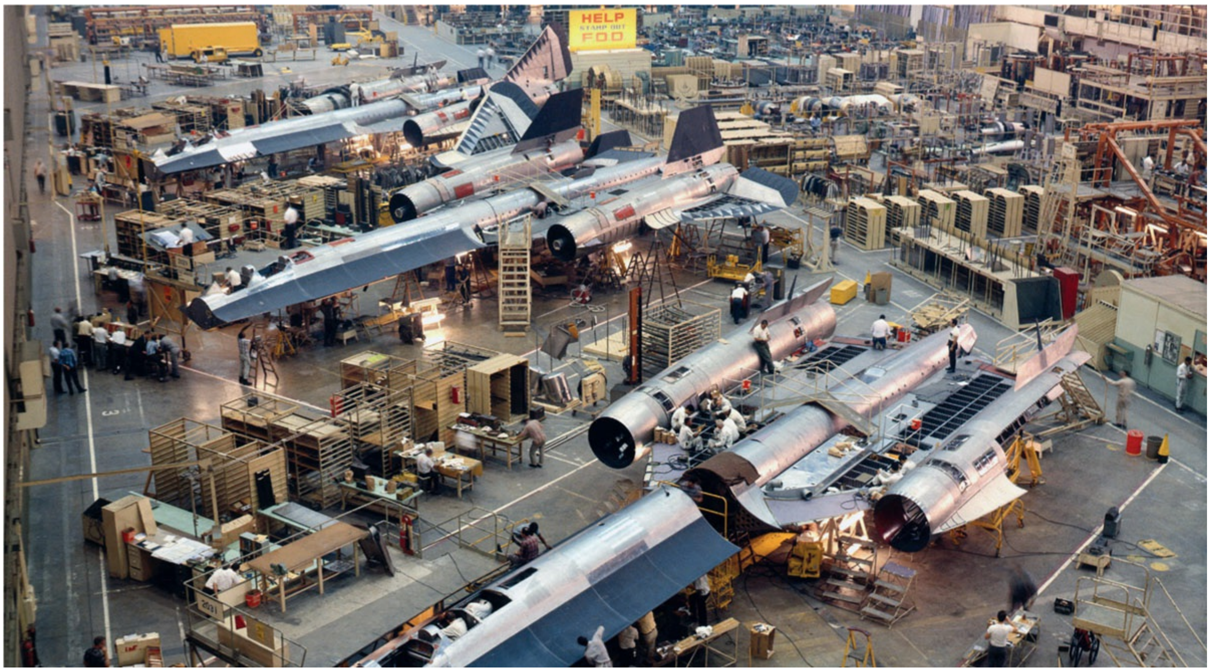


The joining of the forward fuselage at Fuselage Station (FS) 715 (also called the 715 splice) of SR-71A, 61-7954/2005, with the aft fuselage in the fall of 1964. If the F-12B had gone into production, the aft fuselage would have been standard for both the

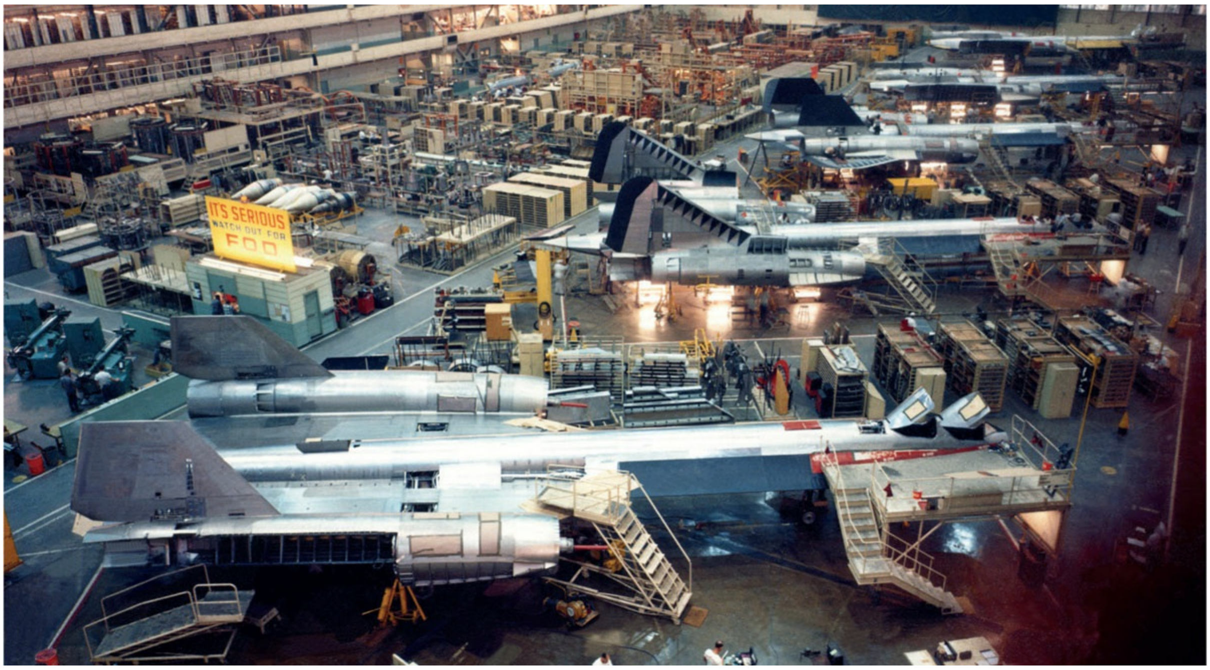
SR-71 and the F-12B. (Author's collection)



SR-71 production line at the Lockheed Skunk Works production facility then located at Hollywood Burbank Airport. From front to back: SR-71A 61-7968/2019; 61-7969/2020; 61-7970/2021; 61-7971/2022; and 61-7972/2023. (Author's collection)

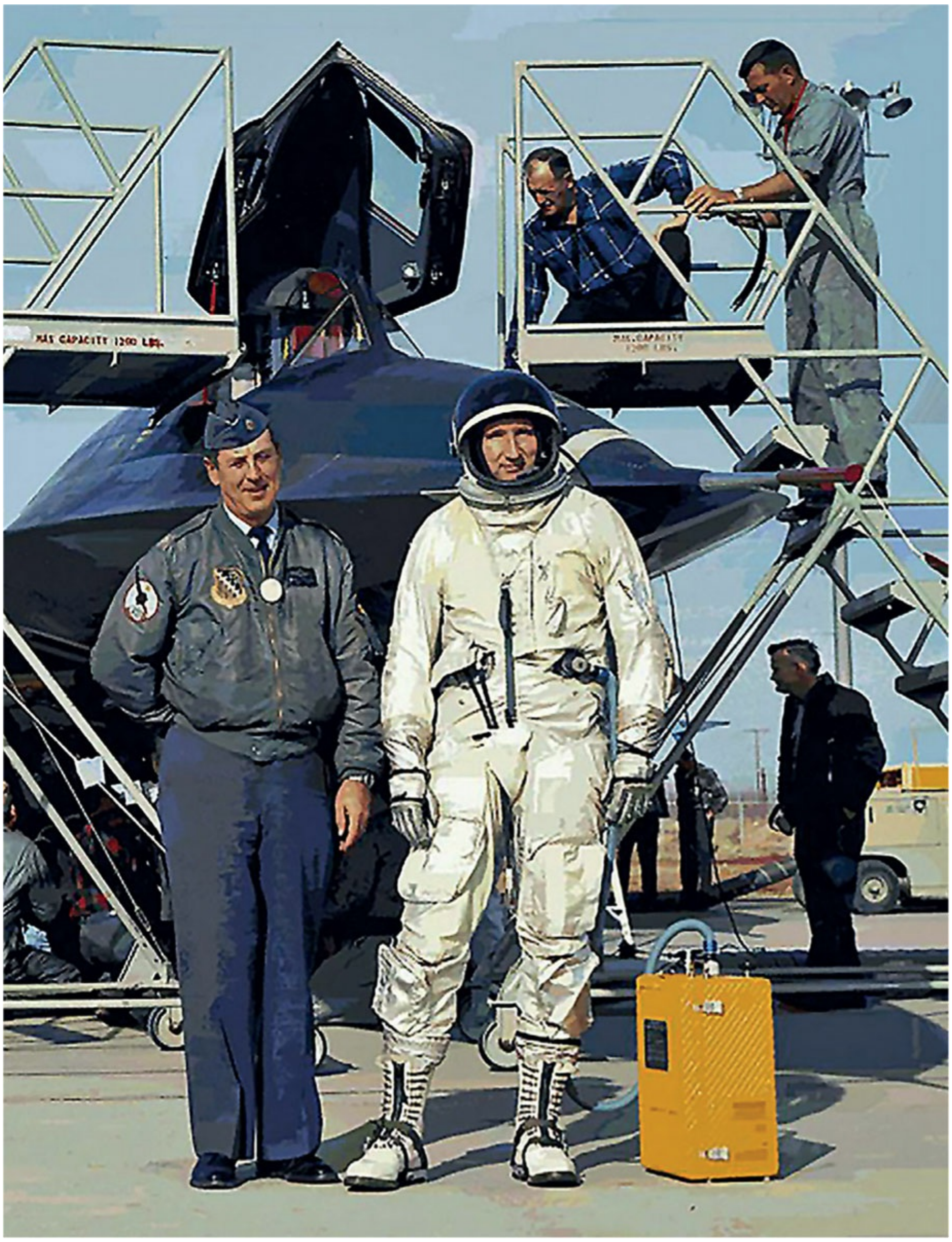

HELP
STAMP OUT
FOD

The last SR-71s on the production line. From the far side of the second level walkway left to right: 61-7977/2028; 61-7978/2029; and 61-7979/2030. (Lockheed Martin)

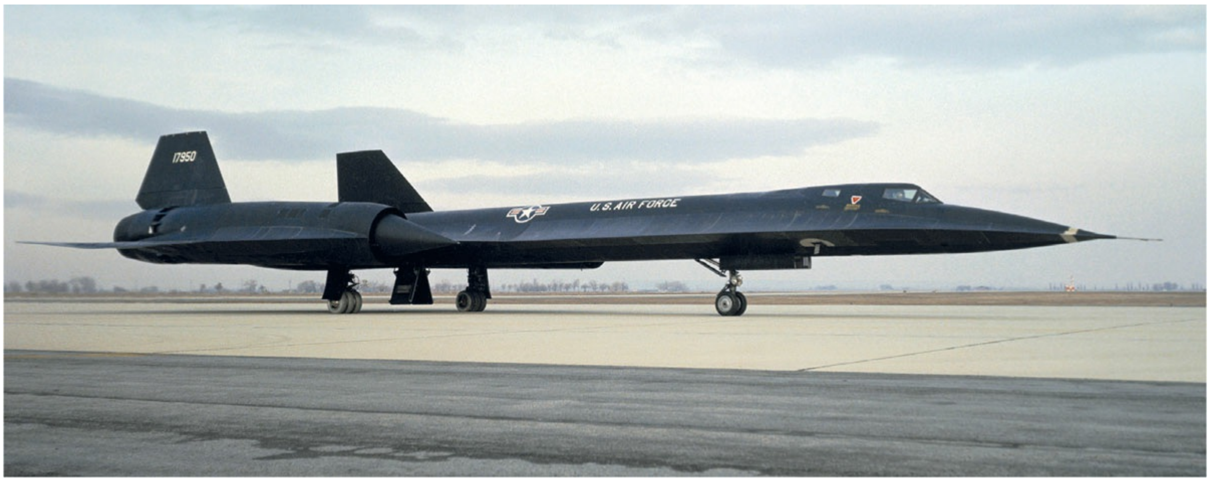

IT'S SERIOUS
WATCH OUT FOR
FOD

A look down the Lockheed Skunk Works assembly bay in Hangar 309/310, with the closest SR-71A, 61-7952/2003 followed by 61-7951/2002 and the number one SR-71A, 61-7950/2001 being the farthest SR from the camera on the production line. (Lockheed Martin)

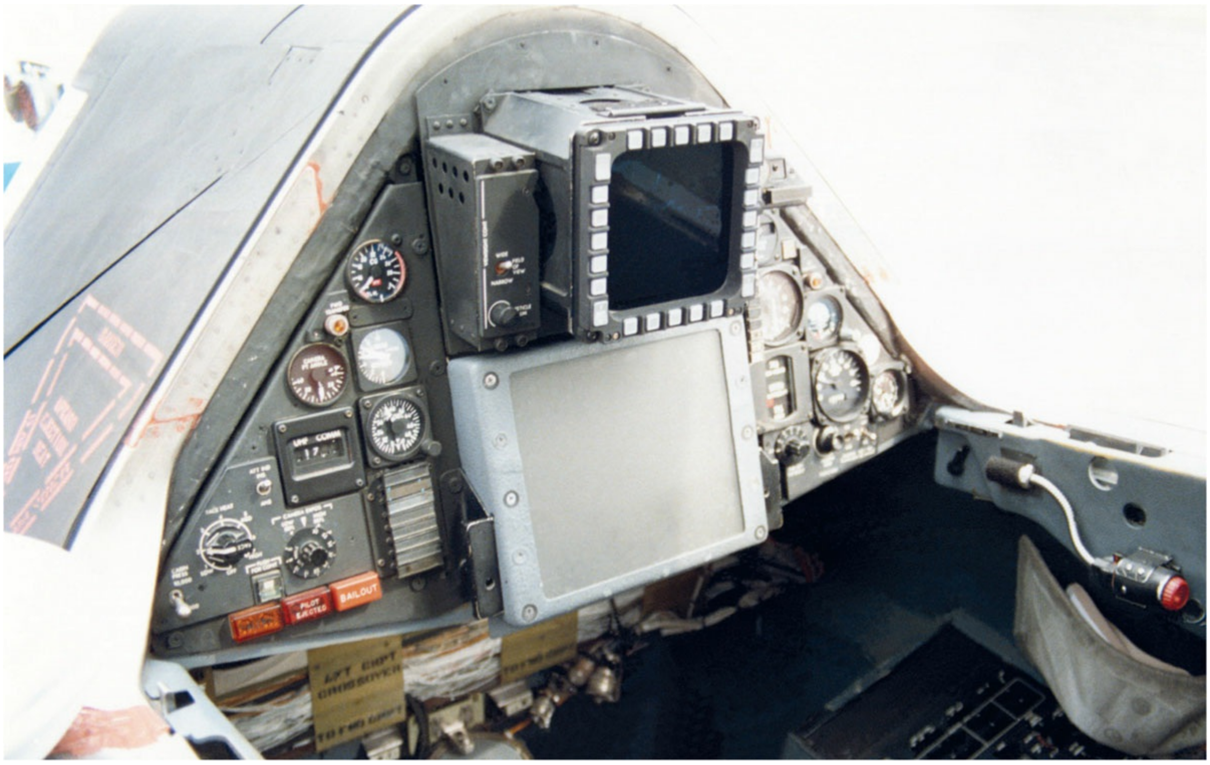
With Skunk Works test pilot Bob Gilliland at the controls, the SR-71A takes to the air for the first time. (Author's collection)


MAX CAPACITY 1200 LBS.
MAX CAPACITY 1200 LBS.

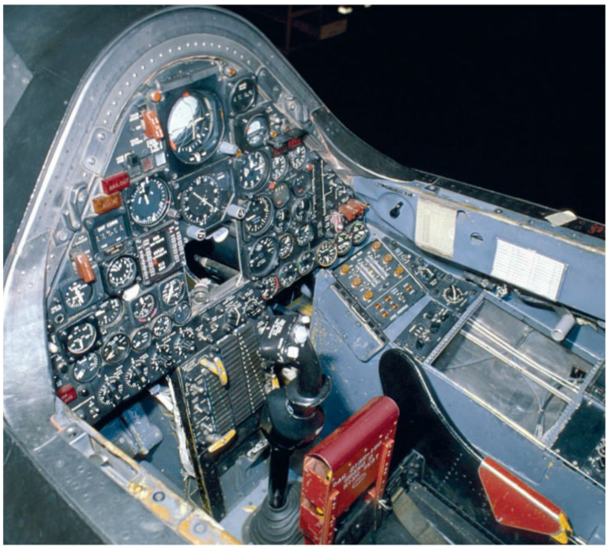
In preparation for the first flight, ground crew and Lockheed technicians work to make sure everything is buttoned up, secured and optimized for the day's first flight. (Author's collection)



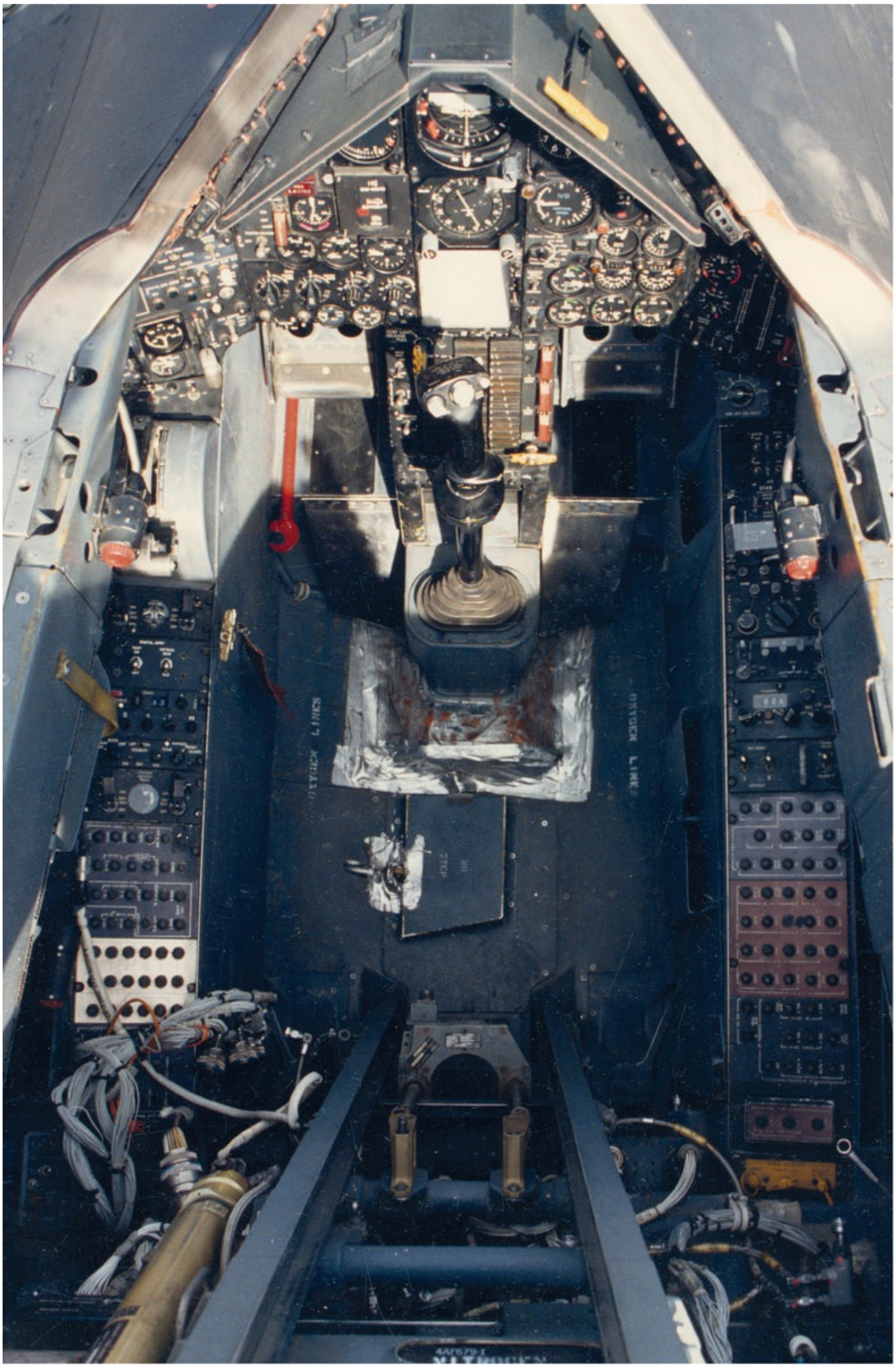
The full-scale development SR-71A, 61-7950/2001, photographed just prior to its very first flight. (Lockheed Martin)



Reconnaissance system officer's (RSO) forward instrument panel. (Author's collection)



The instructor pilot's rear cockpit of the only SR-71C, 61-7081/2000. (James C. Goodall)



SR-71A cockpit from 61-7972/2023. (Lockheed Martin)

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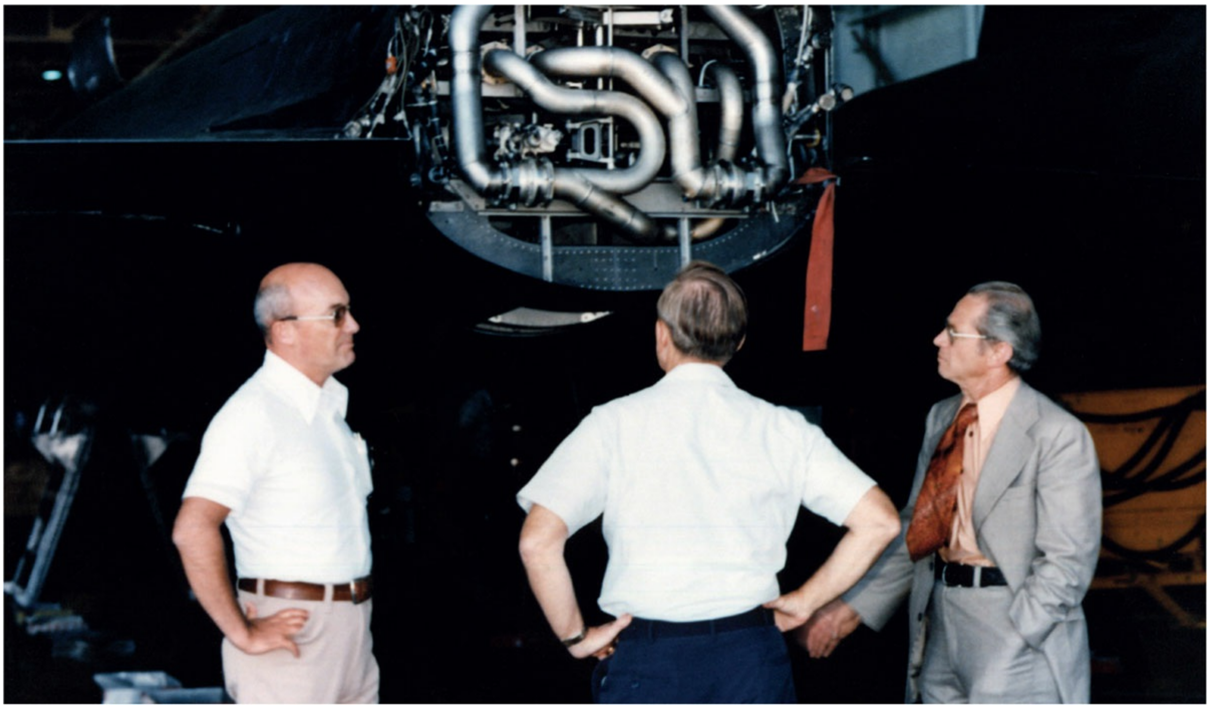
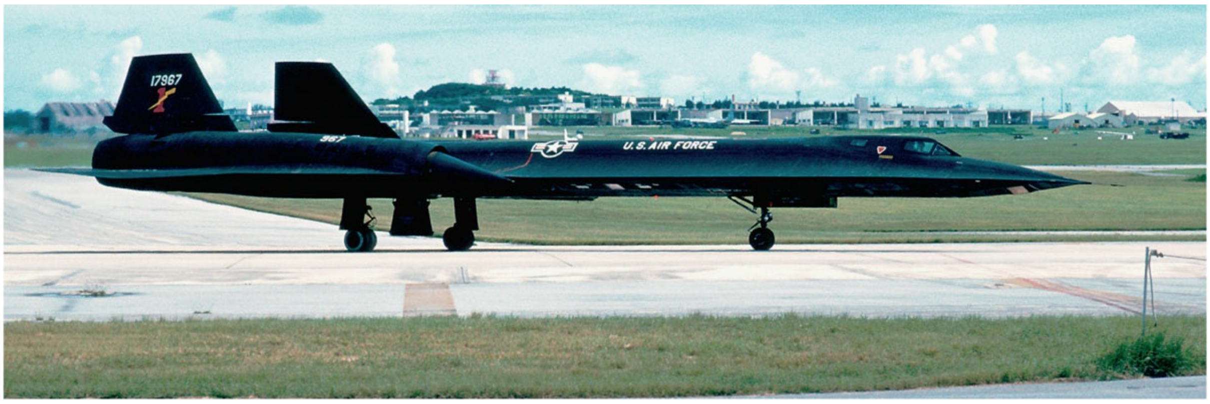
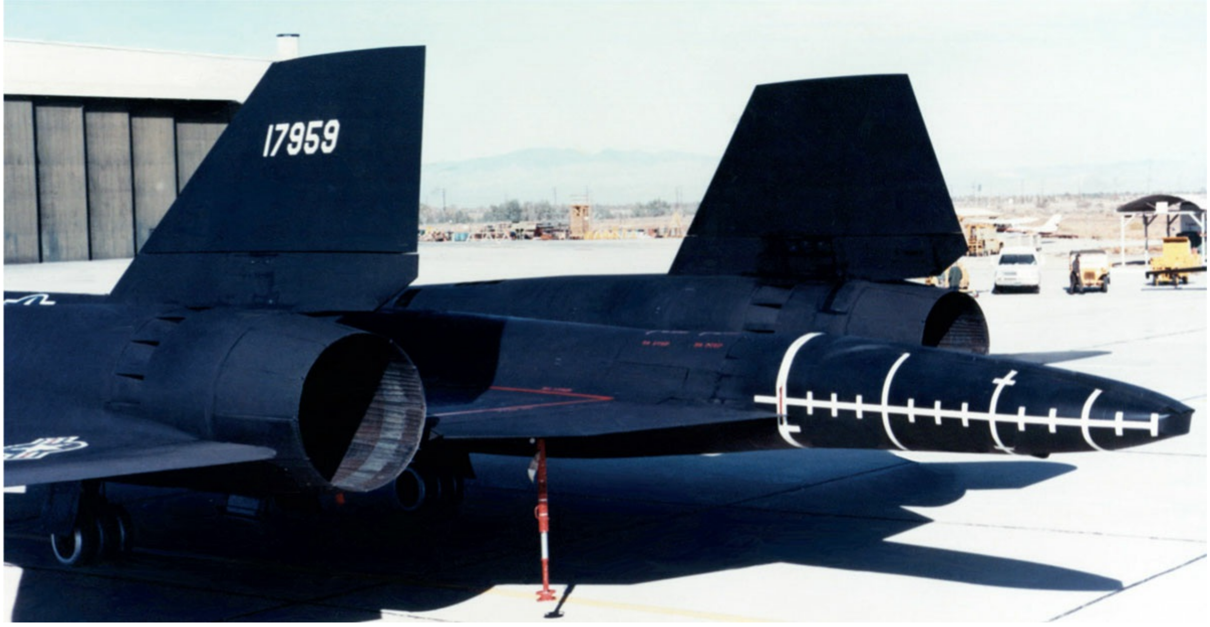
A look-down view of SR-71A/BT 61-7959/2010 from the boom operator position right after completing an air-to-air refueling. (Author's collection)



From left to right: Bob Murphy, Senior Vice President for Manufacturing at the Lockheed Skunk Works; with his back turned, Col Tom Jones, the commander of Air Force Plant 42; and, with the flashy tie, none other than Ben R. Rich, President and General Manager of the Lockheed Advanced Development Projects (ADP) also known as the Skunk Works. (Author's collection)



SR-71A 61-7967/2018 taxis to the Hammer Head at Kadena AB, Okinawa, with its very distinctive "Red One" with a yellow lightning bolt in November 1979. SR '967 was only one of four SRs authorized to carry tail art and only while on deployment to Detachment 1. (Author's collection)



Prior to the SR-71A's first flight as "Big Tail," the new extended tail cone has photo identification markings to properly determine if the "Up/down" movement of the articulated tail cone interferes with the drag chute and runway. (Author's collection)

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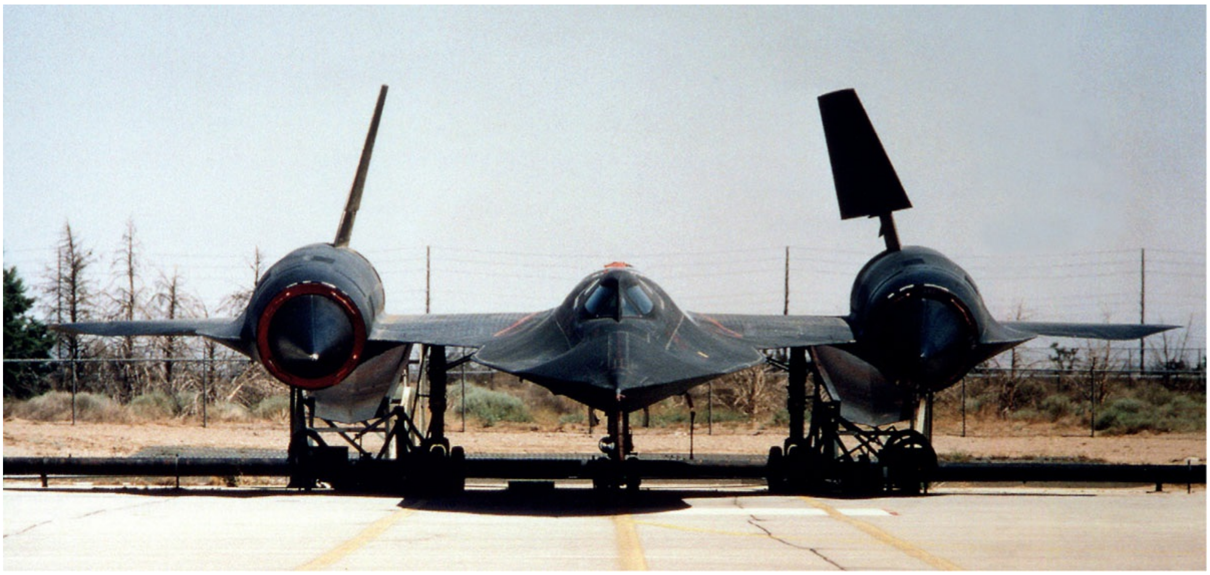
Two SRs at the Hammerhead at Kadena AB, Okinawa. SR-71A 61-7972/2023 and SR-71A 61-7979/2030 get ready to launch in the early 1970s. (Author's collection)



SR-71A 61-7973/2024 is broken and left to bask in the hot Palmdale sun. The SR was flown back to the United States after popping a number of bolts on the 715 splice. ‘973 was never flown again and its last flight was on 21 July 1987. (James C. Goodall)

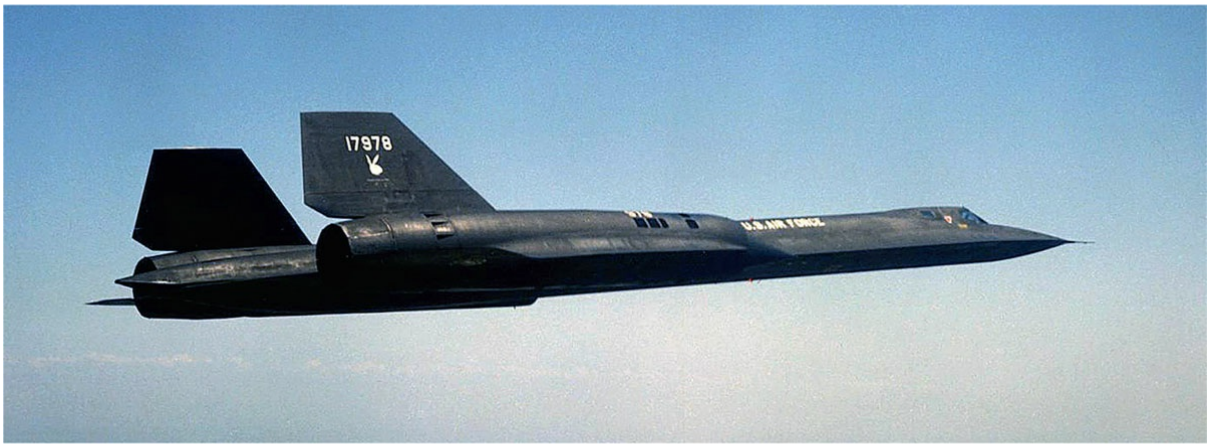
17956
U.S. AIR FORCE

SR-71B 61-7956/2007. Production started on 18 June 1964, with roll out on 20 May 1965. Its first flight took place on 18 November 1965, with crew Bill Weaver and George Andre. Its total flight hours came to 3,967.5, of which 3,760 were flown prior to its being turned over to NASA. ’956 was the very first SR-71 delivered to the Air Force at Beale AFB on 7 January 1966. (Author’s collection)

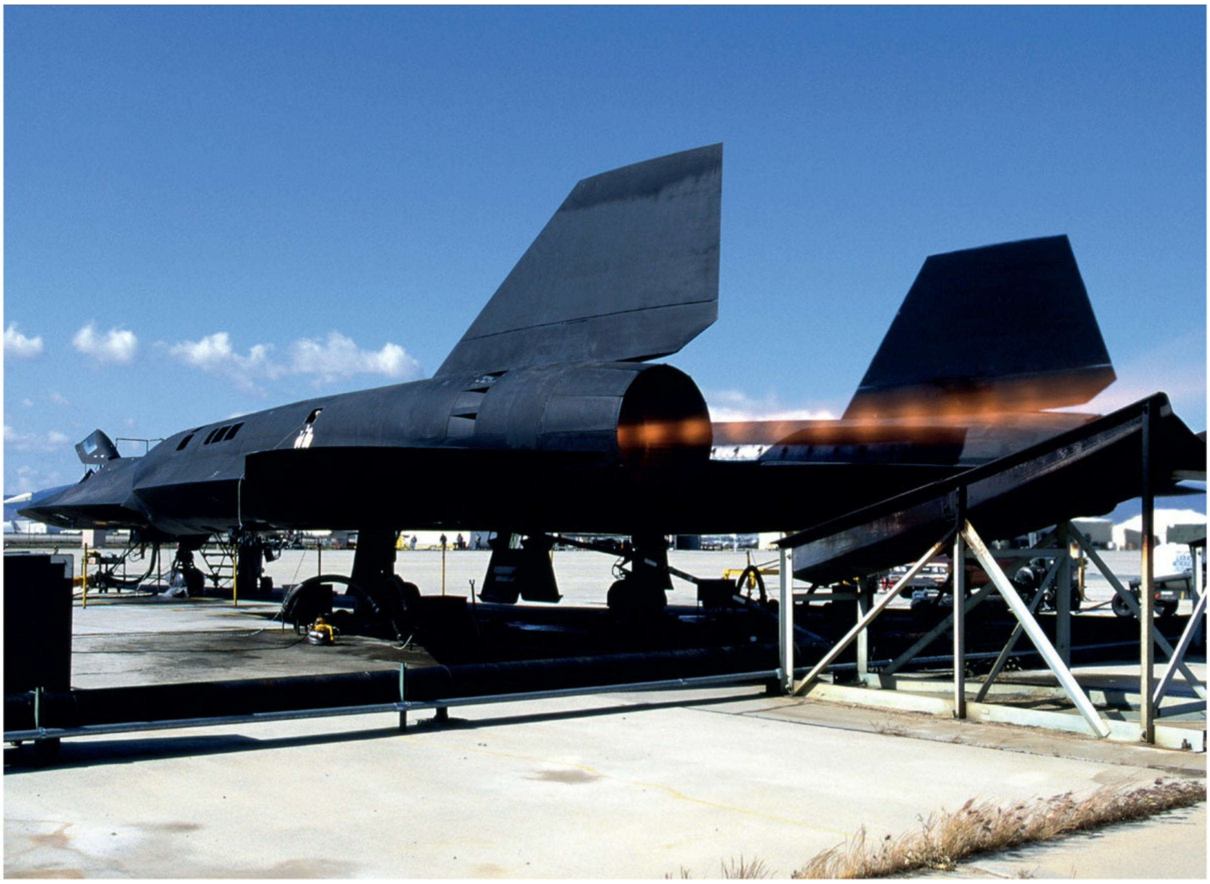
SR-71B 61-7957/2008 heads out of the barn on a training mission on Friday 20 October 1967. Production started on 28 August 1964; roll out took place on 21 June 1965; and its first flight was on 10 December 1965, with crew Bob Gilliland and Jim Eastham. Its last flight was on 11 January 1968. (Lockheed Martin)

17975
U.S. AIR FORCE

SR-71A 61-7975/2026 lifts off of the Beale AFB runway on a very warm and muggy afternoon on 18 February 1981. Production started on 15 March 1966, with roll out on 15 December 1966 and first flight on 13 April 1967, crewed by Darryl Greenamyer and Steven Belgeau. It totaled 2,854 flight hours and made its last flight on 28 February 1990. It was flown to March AFRB Riverside, CA, for display at the base museum. (James C. Goodall)



SR-71A 61-7978/2029. Production started on 13 June 1966 and it was rolled out on 20 March 1967. Its first flight took place on 5 July 1967, with crew Bill Weaver and Steven Belgeau, and it made its last flight on 20 July 1972. (Author's collection)

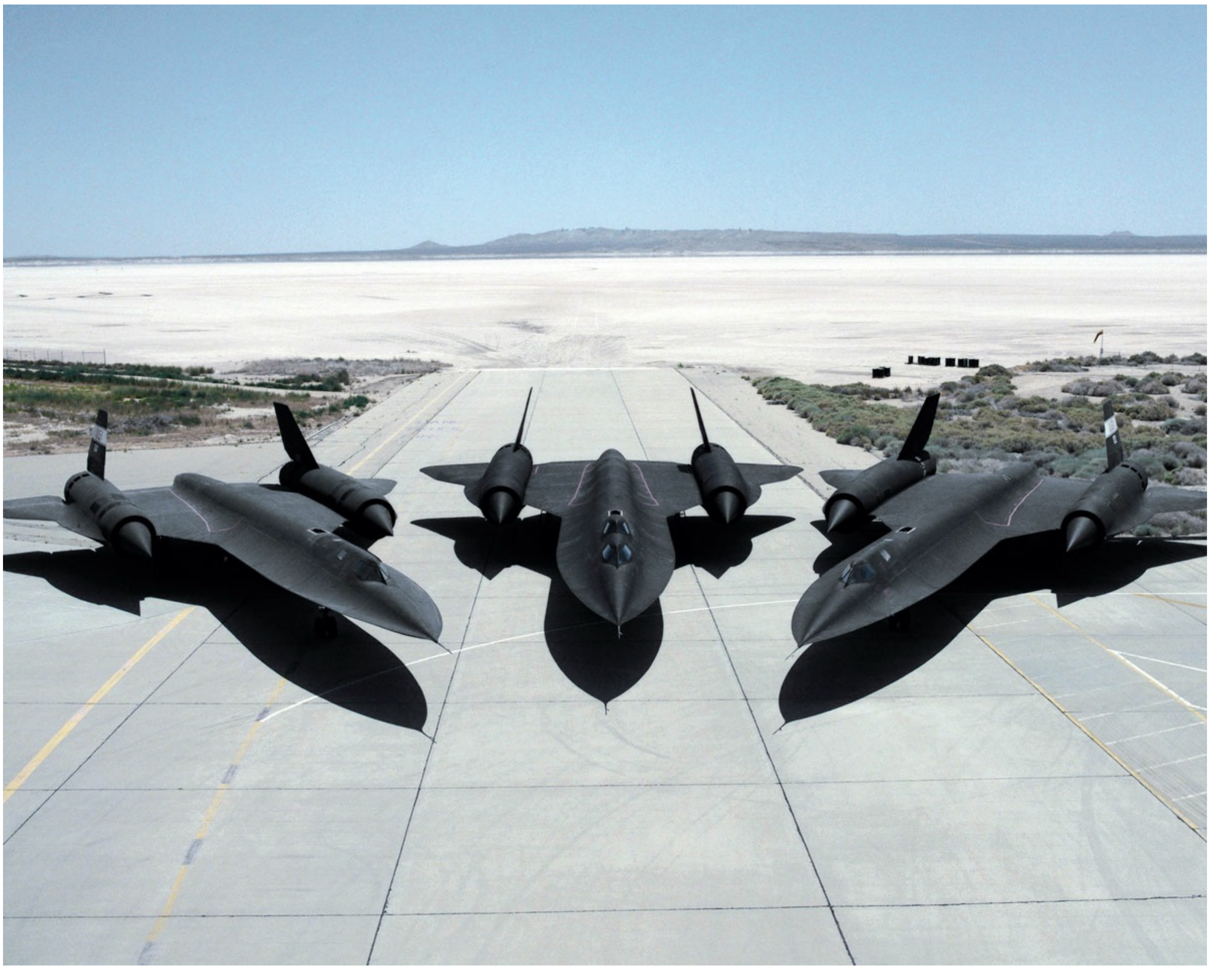


SR-71A, 61-7971/2022 during a full engine run in afterburner on 19 April 1995 at Air Force Plant 42, Site 2, Palmdale, CA. This is the location of the Lockheed SR and U-2 overhaul facility, during testing of the SR for reactivation. (Lockheed Martin)

SR-71A 61-7971/2022, photographed from "General's Hill" at Offutt AFB, NE, for an open house on 19 May 1987. (James C. Goodall)

91474
U.S. AIR FORCE
NASA

YF-12, 60-6935/1002 passes over a snow-covered Mojave Desert near Edwards AFB on this cold 25 November 1964 as it hooks up with a KC-135Q out of March AFB, CA. (Lockheed Martin)



A family portrait of the three SRs assigned to NASA in the early 1990s. From left to right: SR-71A 61-7980/2031, now NASA 844, SR-71B 61-7956/2007, now NASA 831 and SR-71A 61-7971/2020, now NASA 832. (Author's collection)

X-26 FRIGATE

1967

PROGRAM: Q-Star/X-26

Name: Frigate

Mission: Research and training aircraft

Length: 26ft 9in (8.15m)

Wing Span: 57ft 1.5in (17.34m)

Height: 9ft 3in (2.82m)

Max T.O. Weight: 1,430lb (650kg)

First Flight: July 1967

Last Flight: 1969

Crew: 2

Number Built: 7

Power Plant: 1 x Continental O-200 4-cylinder air-cooled engine

Design Speed: Mach 0.21 (158mph; 254km/h)

Service Ceiling: 13,000ft (3,962.4m)

Combat Radius: N/A

Weapons Load: N/A

The X-26 Frigate is the longest-lived of the X-plane programs. The program included the X-26A Frigate sailplane and the motorized X-26B Quiet Thruster (QT) versions: QT-2, QT-2PC and QT-2PCII. All were based on the Schweizer SGS 2-32 sailplane.

The X-26A was used by the United States Navy to train test pilots in the condition of yaw/roll coupling. Since jet trainers were known to be dangerous in this condition, the X-26 was based on the Schweizer SGS 2-32 sailplane. Sailplanes react much more slowly and are easier to control than jet aircraft, making the X-26 a much safer training platform. Four aircraft were originally ordered. Three of the original planes crashed. The US Navy purchased a replacement for each of the crashed units.

Two Schweizer 2-32s (67-15345 and 67-15346 from the US Naval Test Pilot School (USNTPS) X-26 program) were modified to QT-2 configuration by the Lockheed Missiles & Space Company (LMSC) and civil registered as N2471W and N2472W. In 1967 the aircraft were modified by adding a Continental O-200 engine, V-Belt RPM reduction system, four-bladed fixed pitch wood (Fahlin) propeller and airframe upgrades.

After demonstrating quiet flight, the aircraft were again modified to military QT-2PC configuration, known only as tail numbers "1" and "2," with Government Furnished Equipment (GFE) avionics and camouflage for night operation. They were successfully evaluated in Southeast Asia (Prize Crew OpEval) for covert ("stealth") tactical airborne observation in the spring of 1968 (during the Tet Offensive). The two QT-2PCs were returned to USNTPS in 1969 and re-designated X-26Bs.

The 1 QT-2PC was re-designated "67-15345" and the 2 aircraft was used for spare parts. The original X-26 glider version was then designated X-26A. LMSC continued the covert airborne surveillance program with one Q-Star (House Test Aircraft) and eleven pre-production YO-3As.

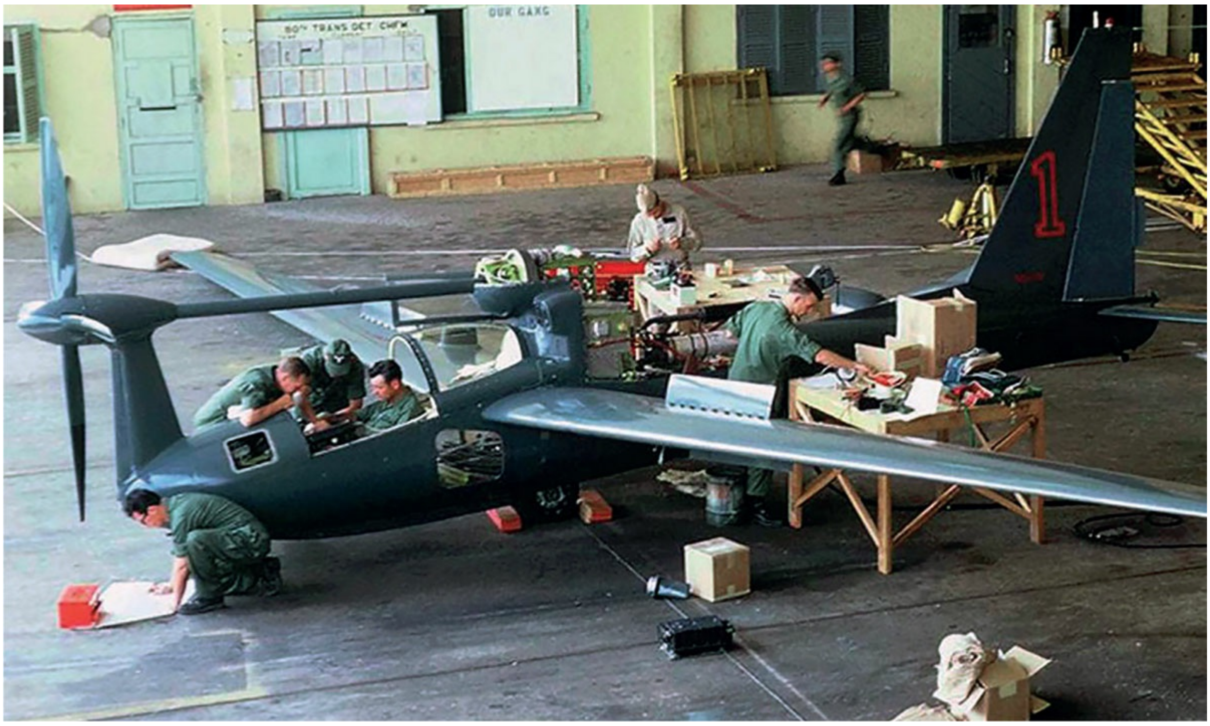
Both of the aircraft from the original QT-2/X-26B program survive today. The X-26B aircraft known as QT-2 N2471W and QT-2PC 1 is located (as of 2019) in the collection of the US Army Aviation Museum at Fort Rucker, Alabama. The original N number N2471W was reassigned in 2019 to another Schweizer SGS 2-32 glider (serial 7, formerly N2758Z) owned by Mile High Gliding of Boulder, Colorado.

The second X-26B aircraft, known as QT-2 N2472W and QT-2PC 2, was restored to SGS 2-32 configuration and has been operated for many years (and known as "72 Whiskey") for paid scenic rides at Mile High Gliding in

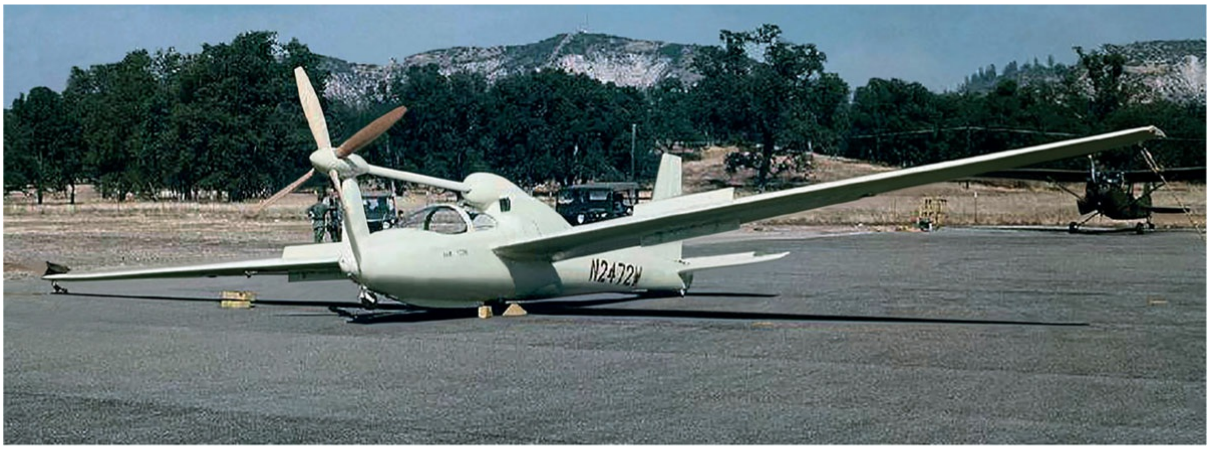
Boulder.

The Q-Star was the first aircraft to use a rotary combustion chamber (Wankel) engine. It is currently being returned to flight status.

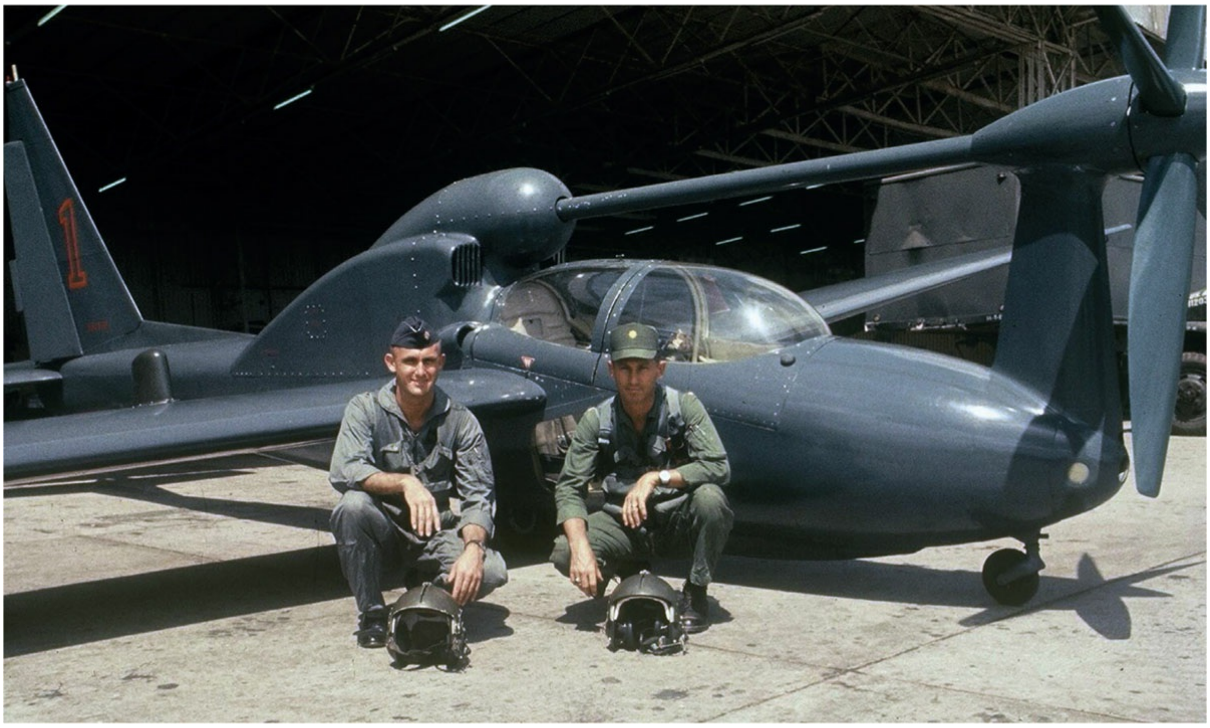
The YO-3As were tactically evaluated in Southeast Asia from mid-1969 to late 1971. They were later used by the Louisiana Department of Wildlife & Fisheries and the FBI in law enforcement, and by NASA for scientific applications. YO-3A 69-18005 is on display at the Museum of Flight in Seattle, Washington. YO-3A 69-18006 is on display at the Pima Air and Space Museum, Tucson, Arizona. YO-3A 69-18007 is in storage at the Western Museum of Flight in Torrance, California. As of 2020, YO-3A 69-18010 (NASA 818) is in flyable storage at NASA's Armstrong Flight Research Center.



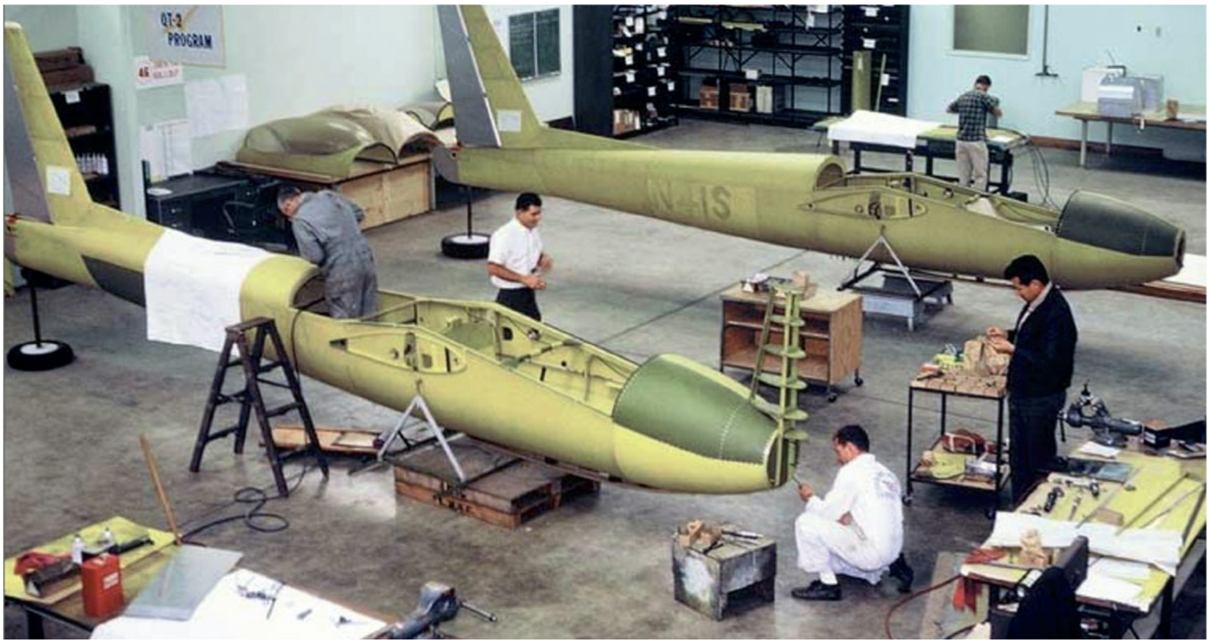
Preflight checkout at the unit's forward operating location base in the Soc Trang Army Airfield hangar, Republic of Vietnam, in 1968. (Author's collection)



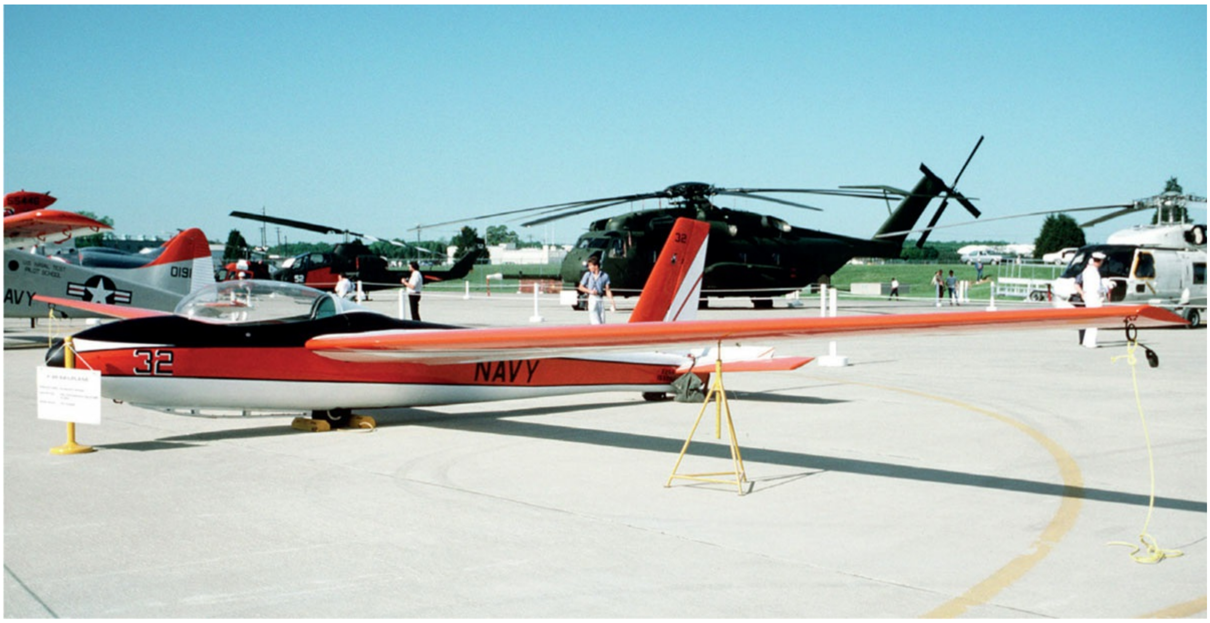
The second of two Schweizer 2-32s, FAA N2472W, serial number 67-15347, from the US Naval Test Pilot School X-26 program which were modified to QT-2 configuration (QT for Quiet Thruster) by the LMSC and civil registered as N2471W and N2472W. (Author's collection)



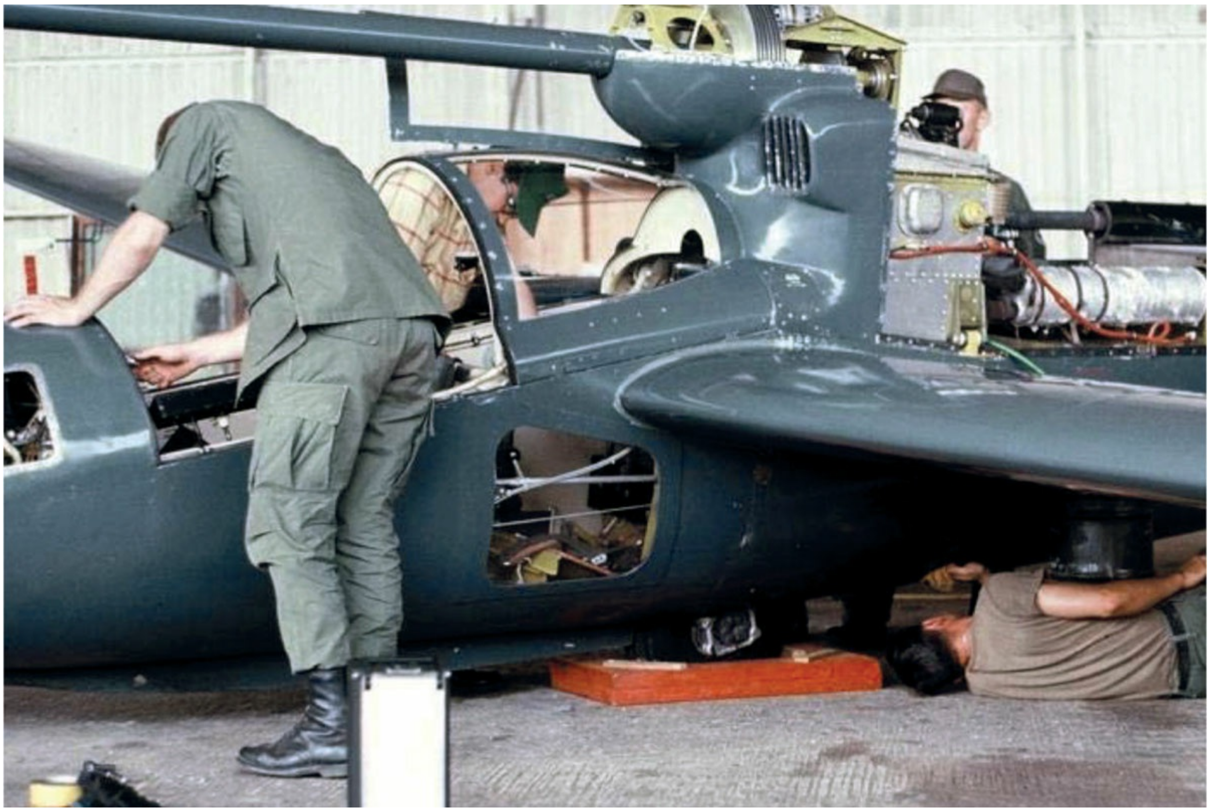
QT-2PC 1 in the Soc Trang Army Airfield hangar in 1968. The QT-2PCs, with their crews, started flying over the hot areas, night after night, and were often launching while under artillery fire. (Author's collection)



Located at Lockheed's modification center at the Tracy Municipal Airport, CA, a team of Lockheed structural and modification specialists begins the changeover from glider to a "quiet spy plane" called the QT-2PC in late 1966. This location was referred to as: "Skunk Works North," as a tribute to the Skunk Works founder, Kelly Johnson. (Author's collection)



An X-26A sailplane on display at an air show at Point Mugu NAS near Ventura, CA, about 80 miles north of downtown Los Angeles. (Author's collection)



With the QT-2PC 2 reassembled after arriving at its operating location, the tri-service ground crew prepares the "Quiet Bird" for flight. (Author's collection)

Off-loading one of two QT-2PCs from an Air Force C-130 at their operating base at the Soc Trang Army Airfield hangar for their six-month long evaluation in a combat environment. (Author's collection)

Ground crewmen at the Soc Trang Army Airfield hangar manhandle the port wing of the QT-2PC shortly after arriving stateside via an Air Force C-130 Hercules. (Author's collection)

AH-56A CHEYENNE

1967

PROGRAM: AH-56A

Name: Cheyenne

Mission: Attack helicopter

Length: 54ft 8in (16.66m)

Rotor Span: 51ft 3in (15.62m)

Height: 13ft 8.5in (4.18m)

Max T.O. Weight: 25,880lb (11,740kg)

First Flight: 21 September 1967

Last Flight: 10 April 1969

Crew: 2

Number Built: 10

Power Plant: 1 x General Electric T64-GE-16 turboshaft

Design Speed: Mach 0.3 (225mph; 362km/h)

Service Ceiling: 20,000ft (6,100m)

Combat Radius: N/A

Weapons Load: 1 x nose turret; 1 x belly turret and 7 x hard points

In the 1960s, the Army tested the AH-56A Cheyenne, an attack helicopter that might have revolutionized warfare. Had a civilian version existed, it might have changed aviation. Instead, the Cheyenne became a "might have been." It was costly and technologically challenging. It may have been too advanced for its time. Its performance in flight was sometimes "spectacular," as one pilot put it, but there were minor kinks that were never quite ironed out.

The AH-56A was also called the Advanced Aerial Fire Support System (AAFSS). During the period when the United States was building up its troop strength in Vietnam, the AH-56 became a bold attempt to compete with the Air Force for a key role in air-to-ground support. The Cheyenne was a highly sophisticated compound rotorcraft incorporating design features pioneered in Lockheed's earlier XH-51A test ship.

It was a long, slim helicopter with retractable landing gear, small wings that spanned almost 27ft, and a General Electric T64-GE-16 shaft turbine engine with a four-bladed rotor. The power rating of the engine was increased to 3,922hp as the test program evolved. The Cheyenne used an innovative propulsion system built around the T64. The power plant drove a rigid, four-bladed, gyro-stabilized main rotor, the tail-mounted anti-torque rotor, and the pusher propeller at the extreme end of the tail boom. During vertical and hovering flight all power was applied to the main and anti-torque rotors, while during forward flight all but about 700shp was shafted to the pusher propeller. In forward flight the stub wings and wind milling main rotor generated lift. In "clean" configuration the AH-56A was capable of sea-level speeds in excess of 275mph.

The Army was looking for a truly giant leap with the AH-56. The service established exceedingly ambitious goals. It said it wanted an aircraft with a top speed of 220kt, able to hover out of ground effect at 6,000ft, with a ferry range of 2,100 nautical miles. A little noticed feature of the Cheyenne was its ability to self-deploy over long distances, including the 2,200-mile flight from California to Hawaii. Although Lockheed had little experience building helicopters, the Army chose its design in 1966.

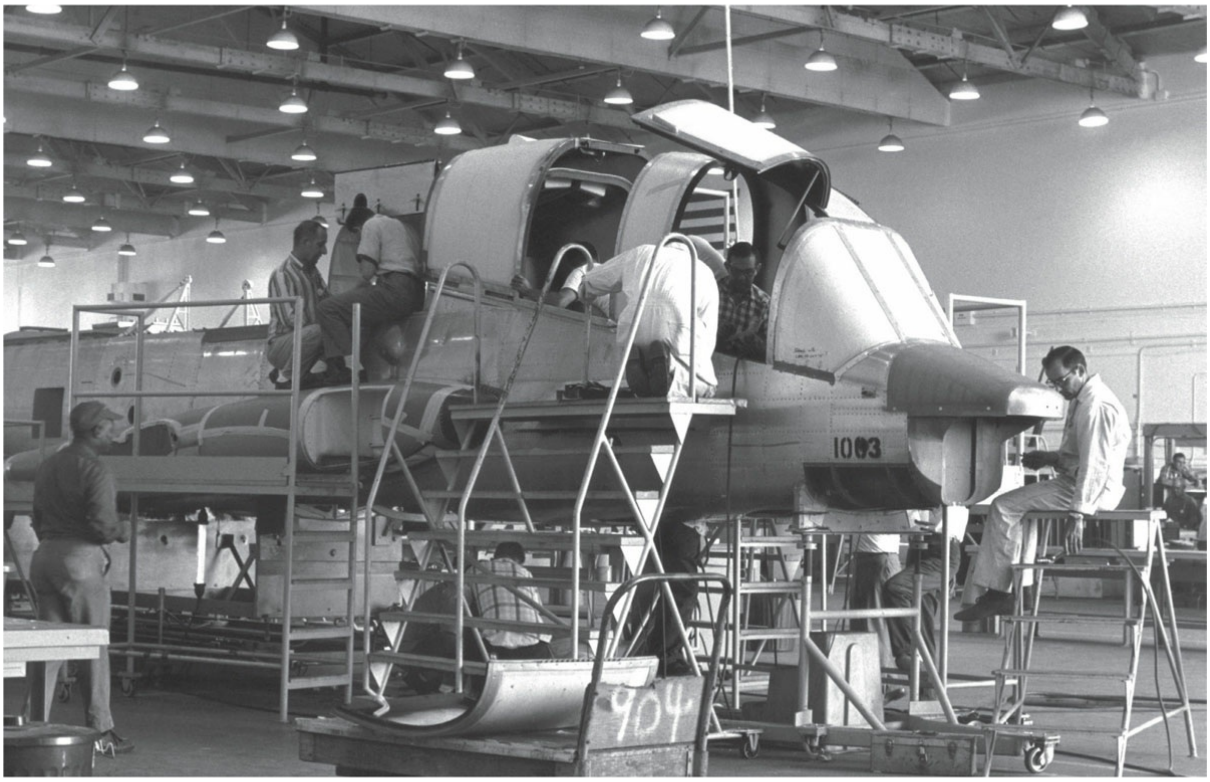
The crew of two, pilot and gunner/co-pilot, sat in tandem in an enclosed cockpit. The impressive armament of the Cheyenne included a 30mm XM140 cannon in a belly turret, and a 40mm XM129 grenade launcher or 7.62-mm minigun in a nose turret. Under the wing were six hard points for ordnance, consisting of Hughes TOW anti-tank missiles or 2.75in folding fin aircraft rockets. The AH-56 had an advanced weapon sighting system that included night vision equipment and a helmet gun sight. The Army was enthusiastic enough that in January 1968, it placed an initial production order for 375 aircraft. As it turned out, only ten Cheyennes were built. With Army Lt Col Emil "Jack" Kluever on board, test pilot Donald R. Segner took the prototype AH-56 for its first flight at Van Nuys Airport on 21 September 1967. But in tests the AH-56 had difficulty maintaining stability close to the ground and at high speed. Various design changes seemed to help, but no certain fix had been found when the third Cheyenne built was lost in a crash on 12 March 1969.

Following the grounding of the AH-56s, tests resumed in July 1969. By then the Army had abandoned its production order – prematurely, many observers said. The Cheyenne program had also suffered from cost increases. Meanwhile, the Army was getting good results with a less advanced, less ambitious helicopter, the AH-1G Huey Cobra, which went into combat in South Vietnam in October 1967.

Had its technical difficulties been overcome and had politics not intervened, the Cheyenne would have been a formidable weapon. In some ways, it was more advanced than today's AH-64D Longbow Apache, which offers some of the capabilities the Cheyenne had but is not as effective at high altitude. The Cheyenne "was an incredible aircraft," said Richard Berch, who piloted the AH-56A at the Yuma Proving Ground in Arizona. "It would have changed military aviation. A passenger carrying version would have changed short-haul commercial aviation."

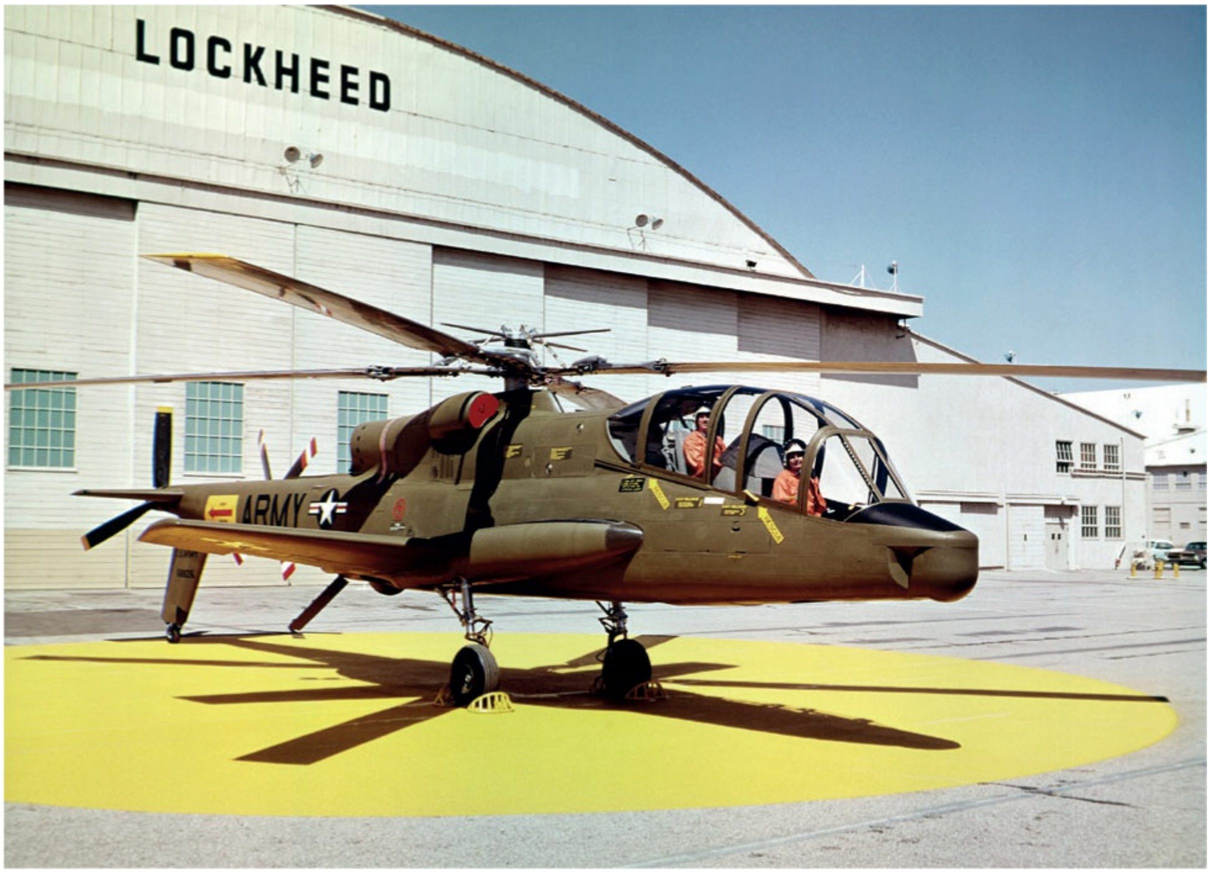
ARMY
U.S.ARMY
17501

The AH-56A Cheyenne full-scale mockup at Van Nuys Airport in southern California in the spring of 1966. (Lockheed Martin)

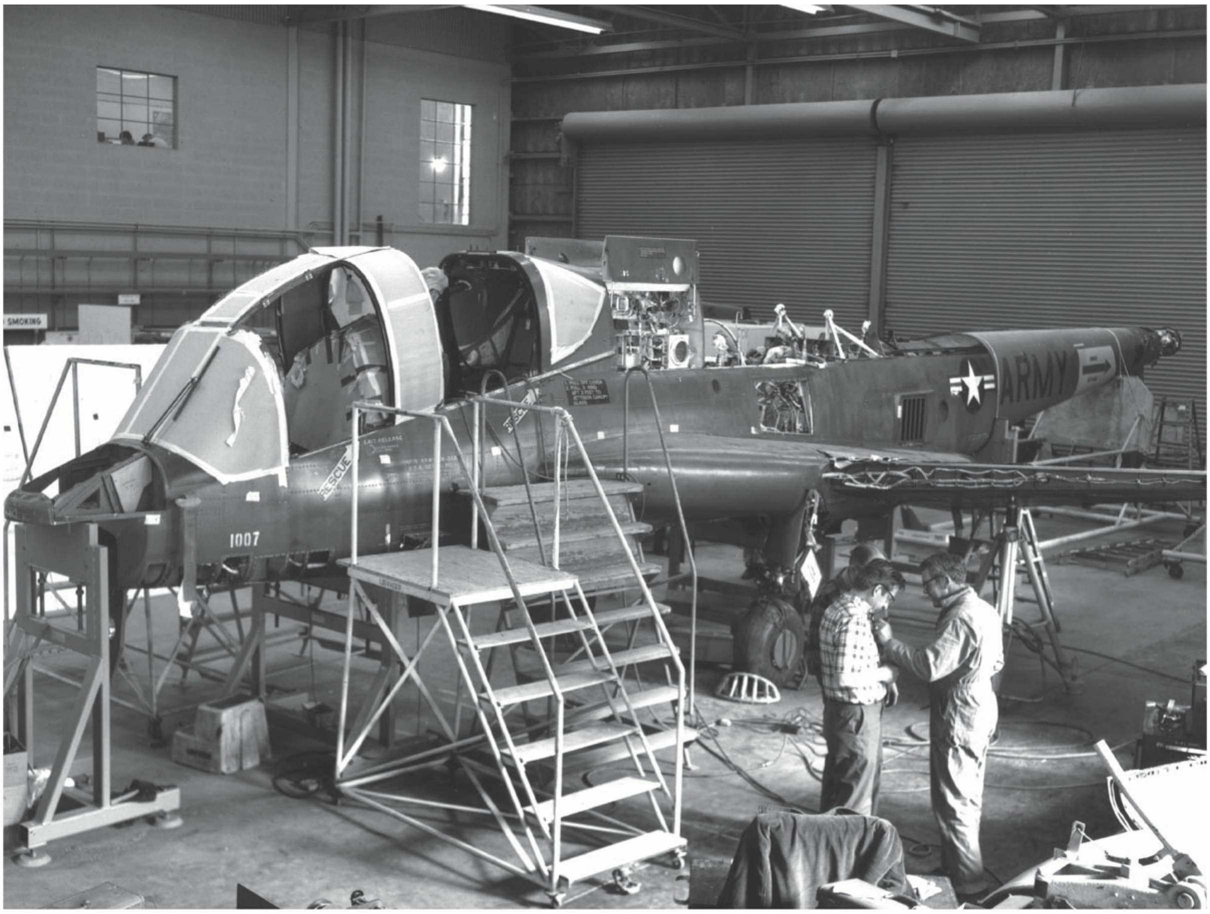


AH-56A production line showing the almost complete airframe 1003. (Lockheed Martin)

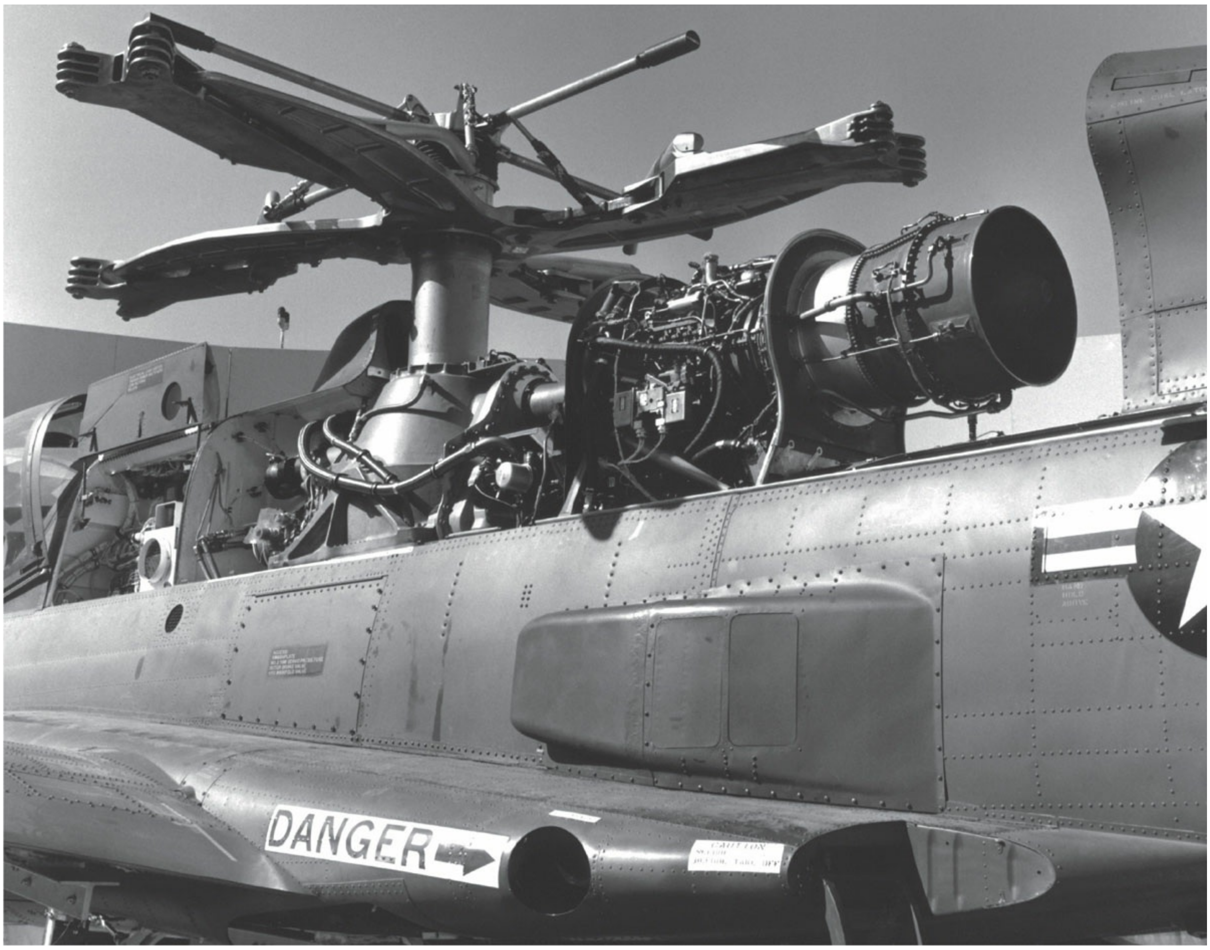
LOCKHEED



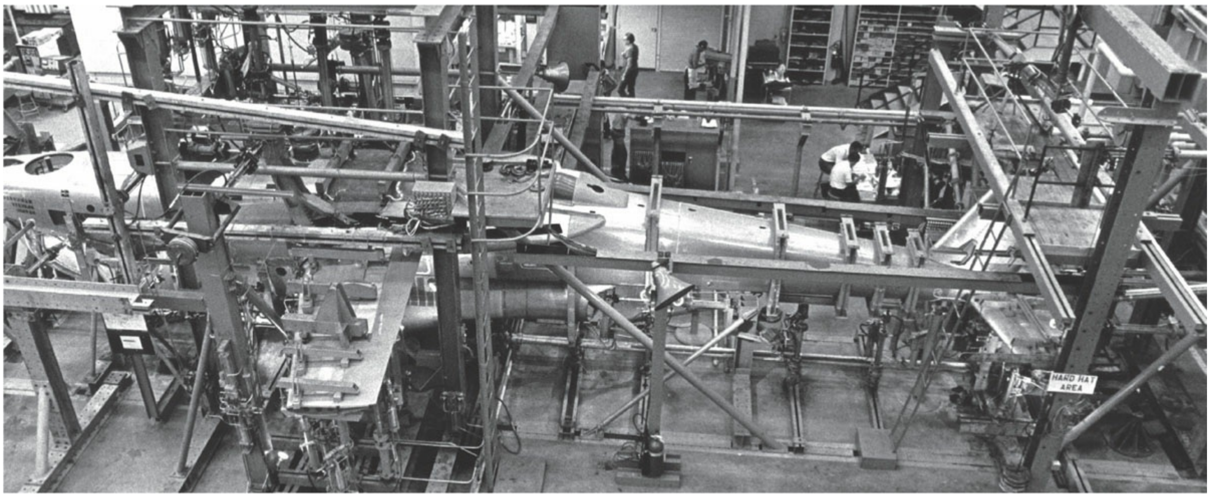
The first production AH-56A, serial number 1001, as it is rolled out of its hangar to show to Army brass at Van Nuys Airport in the fall of 1966. (Lockheed Martin)


1007
ARMY
RESCUE
SMOKING

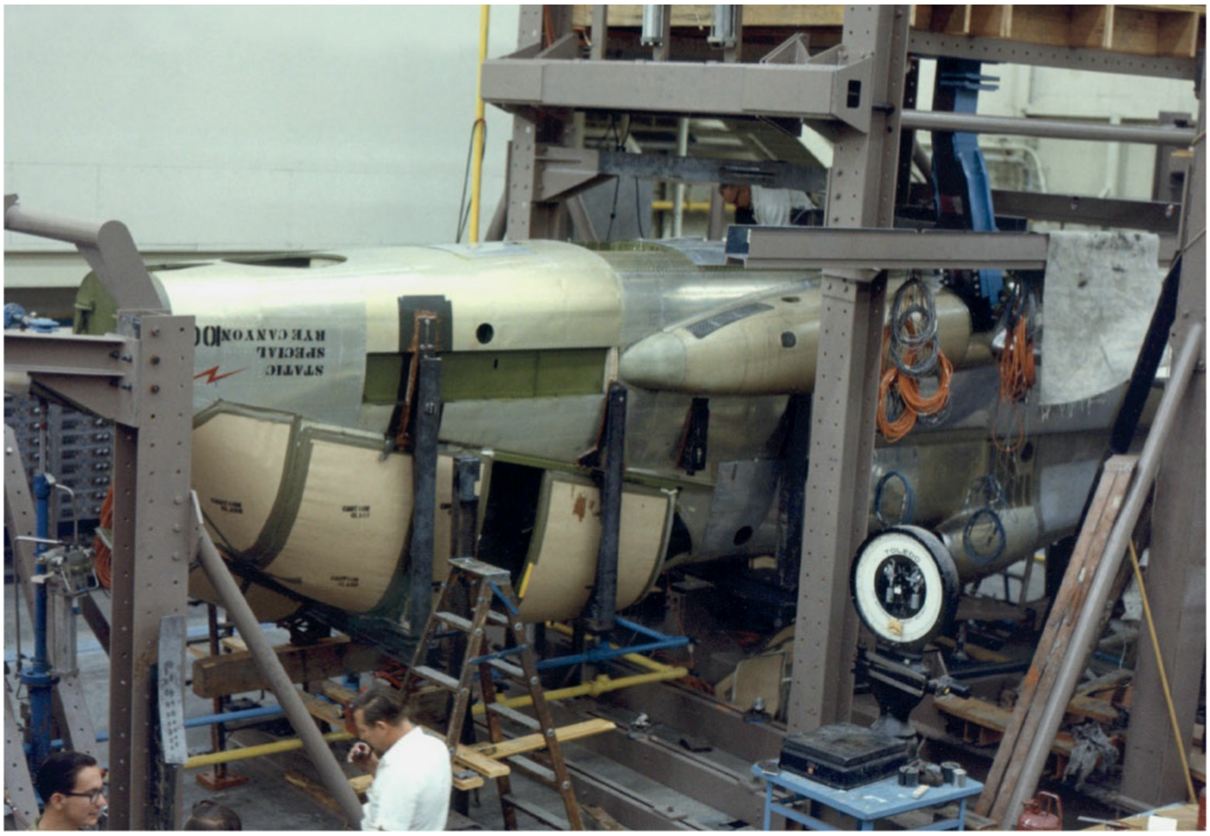
In the assembly fixture the seventh AH-56A is nearing completion. (Lockheed Martin)



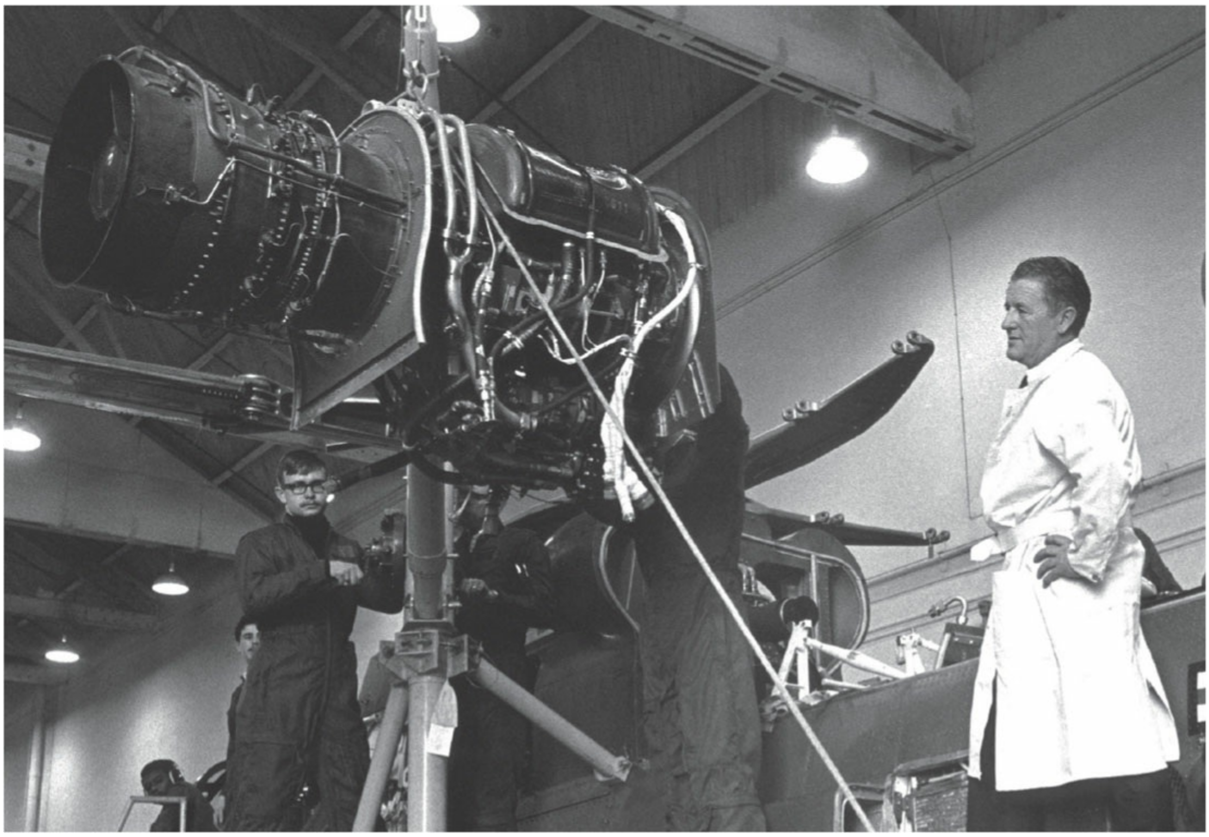
A closeup view of the AH-56A's power plant, the General Electric T64-GE-16 turboshaft engine. (Lockheed Martin)



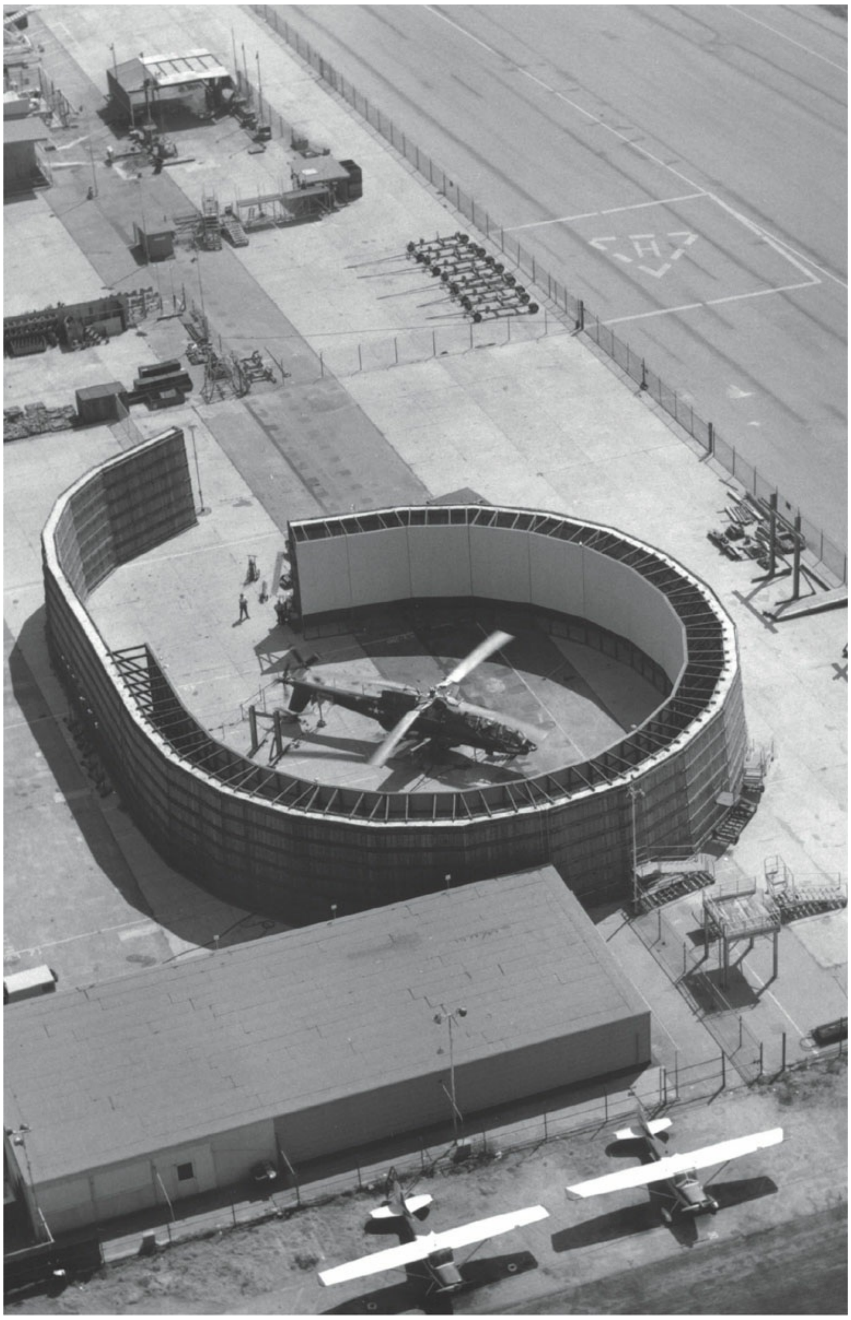
The static airframe for the AH-56 Cheyenne is seen undergoing stress and fatigue testing in this special fixture at the AH-56s production site at Van Nuys Airport. (Lockheed Martin)


STATIC
SPECIAL
RYE CANYON 100
TOLEDO

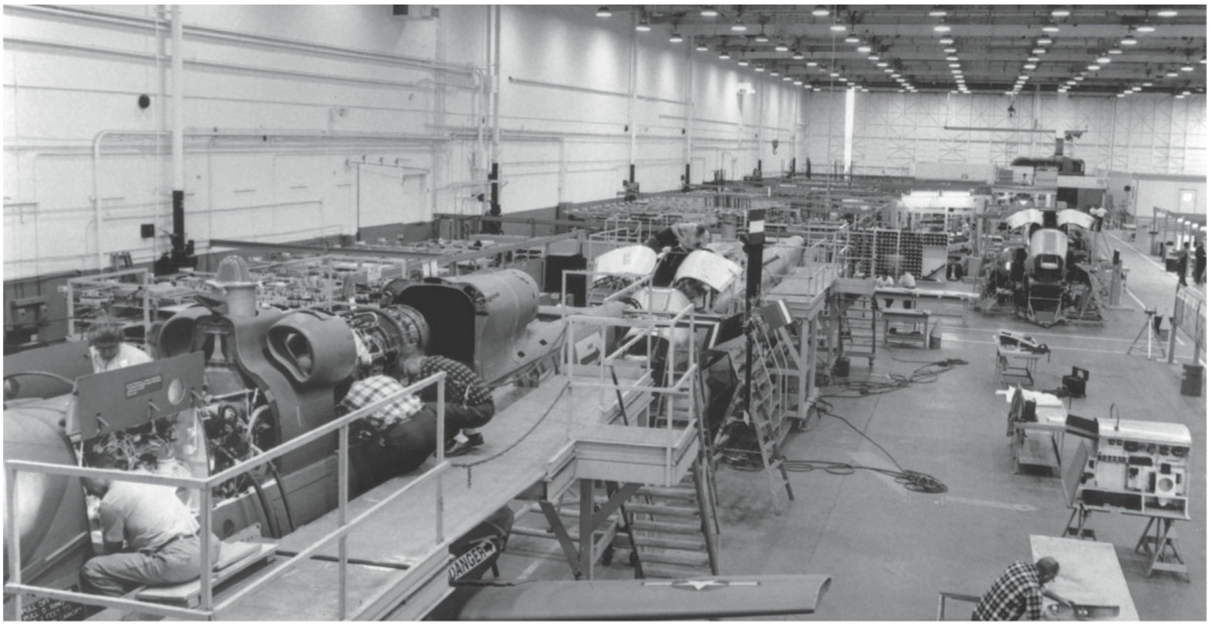
Sometimes it is easier to work on a large aircraft when testing the airframe if you can just work on it upside down. In this color photo, the AH-56, ship #1000, is undergoing structural fatigue testing. (Lockheed Martin)



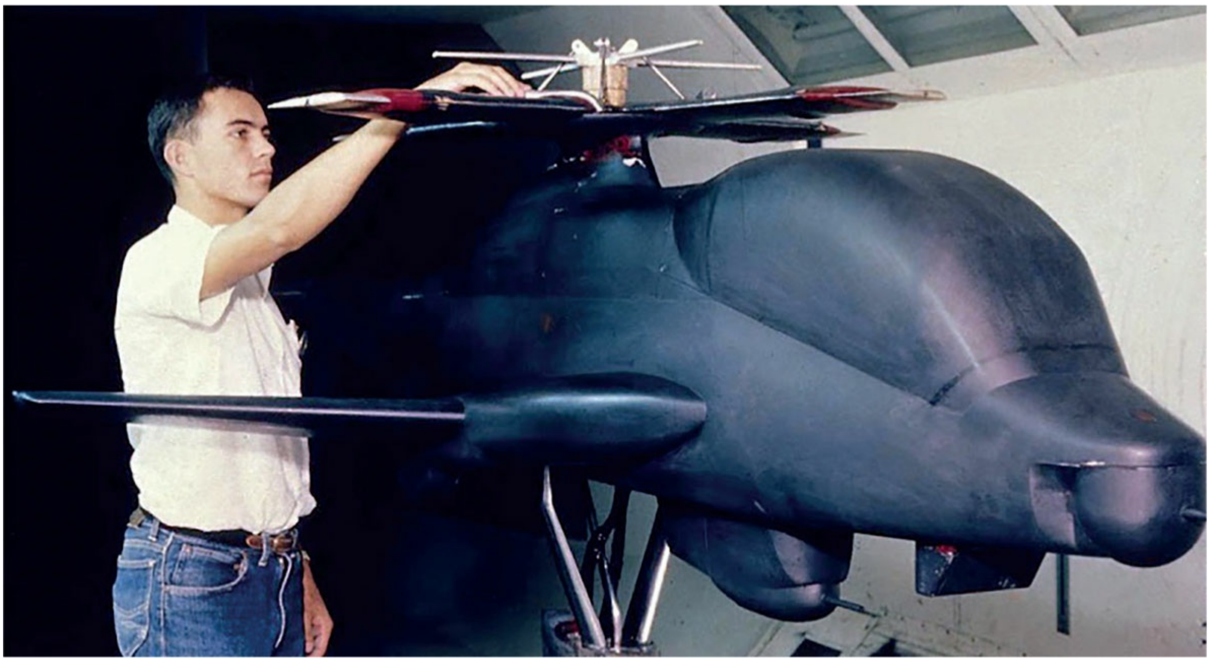
The General Electric T64-GE-16 turboshaft engine being installed into the AH-56A Cheyenne. (Lockheed Martin)



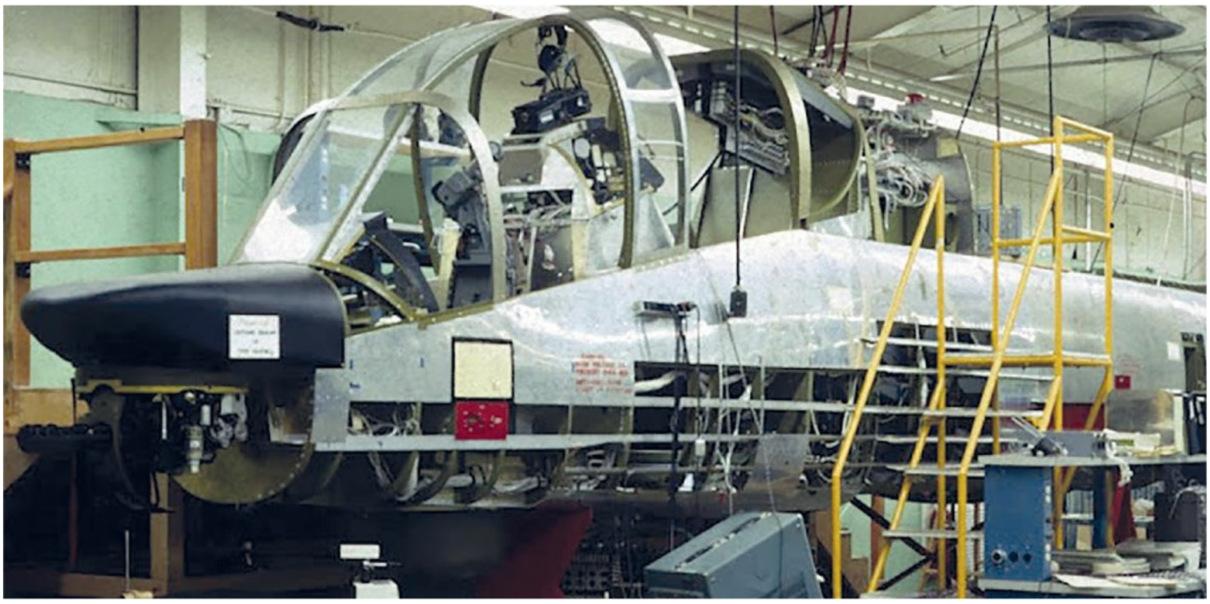
One of the ten AH-56A Cheyennes is being readied for a high-speed rigid rotor test at the Van Nuys Airport location. This test area for the AH-56A was called "Fort Cheyenne" and was designed to prevent the loss of the main rotor blade from the enclosure if the blades decided to come apart. (Lockheed Martin)



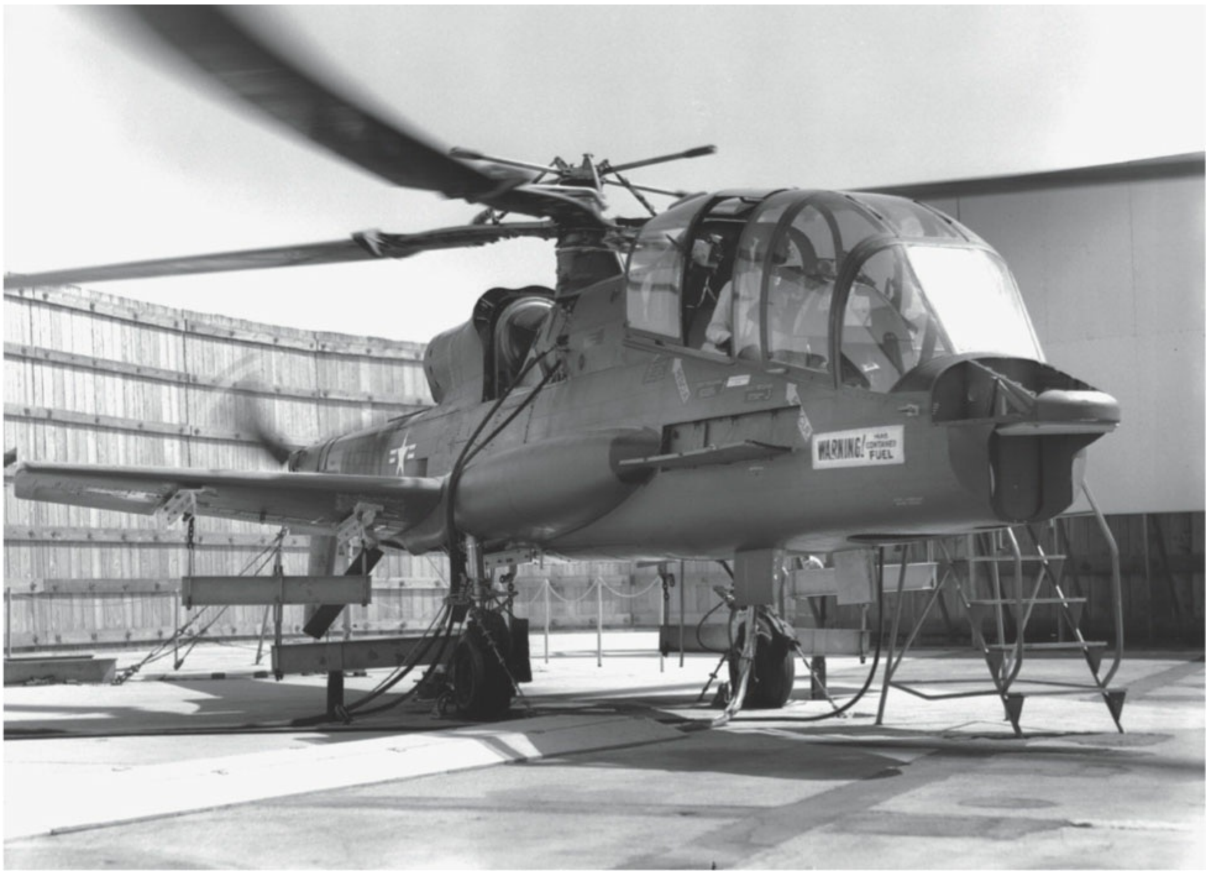
AH-56A Cheyenne production line at the Lockheed facility at Van Nuys Airport. (Lockheed Martin)



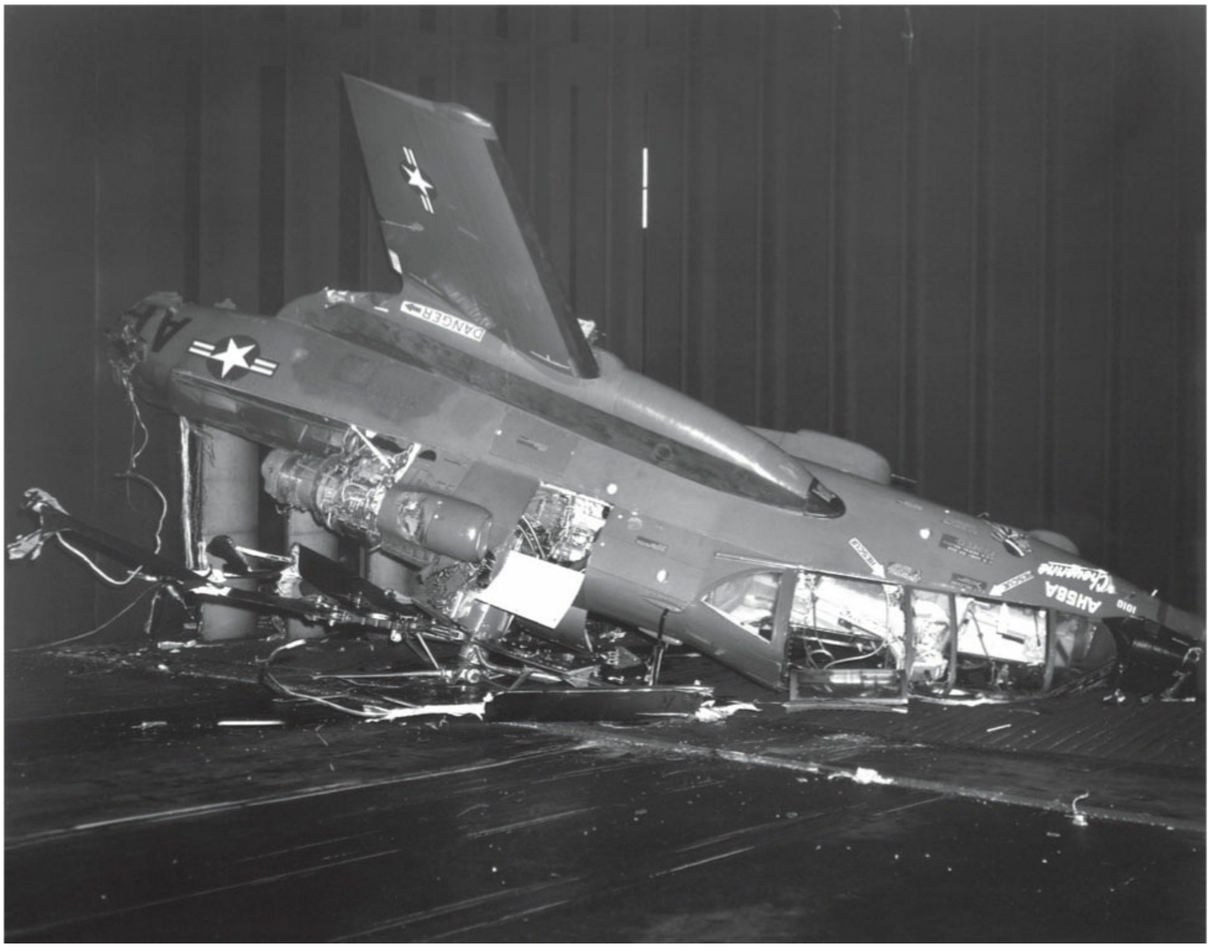
Wind tunnel model of the AH-56 testing airflow over the canopy and wing assembly to see if it interfered with rigid blades. (Lockheed Martin)



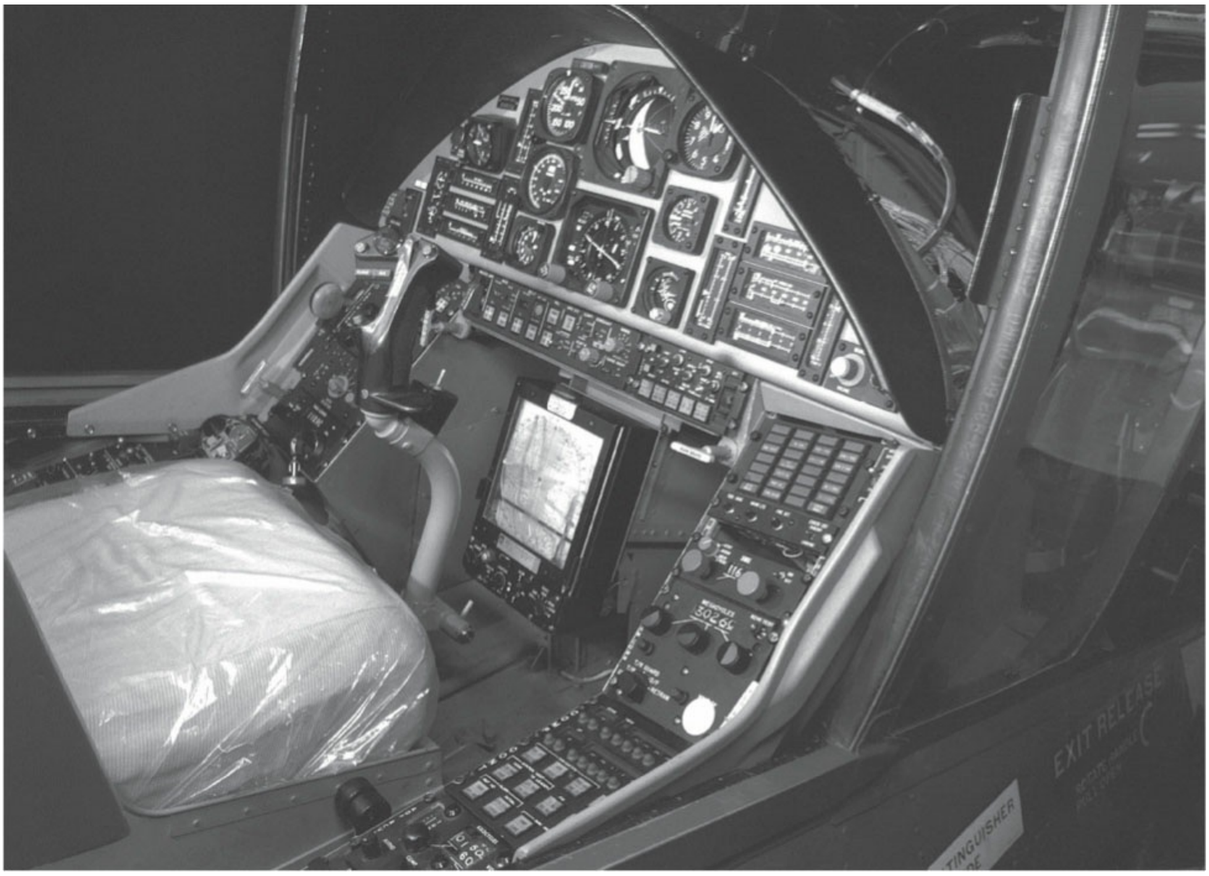
The first AH-56A Cheyenne is seen in its production fixture during assembly. (Author's collection)


WARNING!
TANKS CONTAINED FUEL

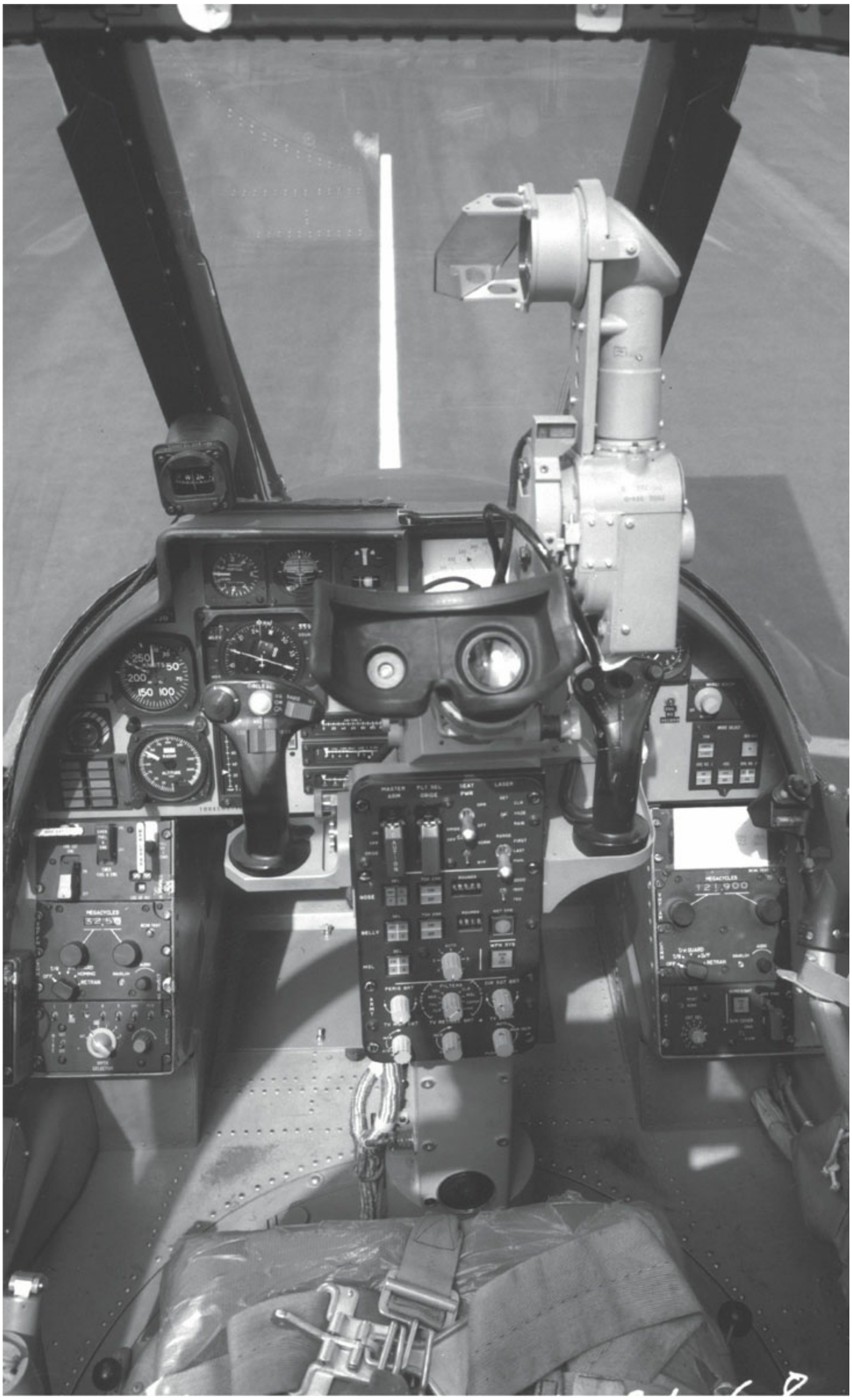
The first AH-56A is in the rotor test enclosure, also known as "Fort Cheyenne," as Lockheed technicians run the AH-56A through its paces by taking all three rotors to its maximum deflection. (Lockheed Martin)


DANGER
AH56A
Cheyenne
1010

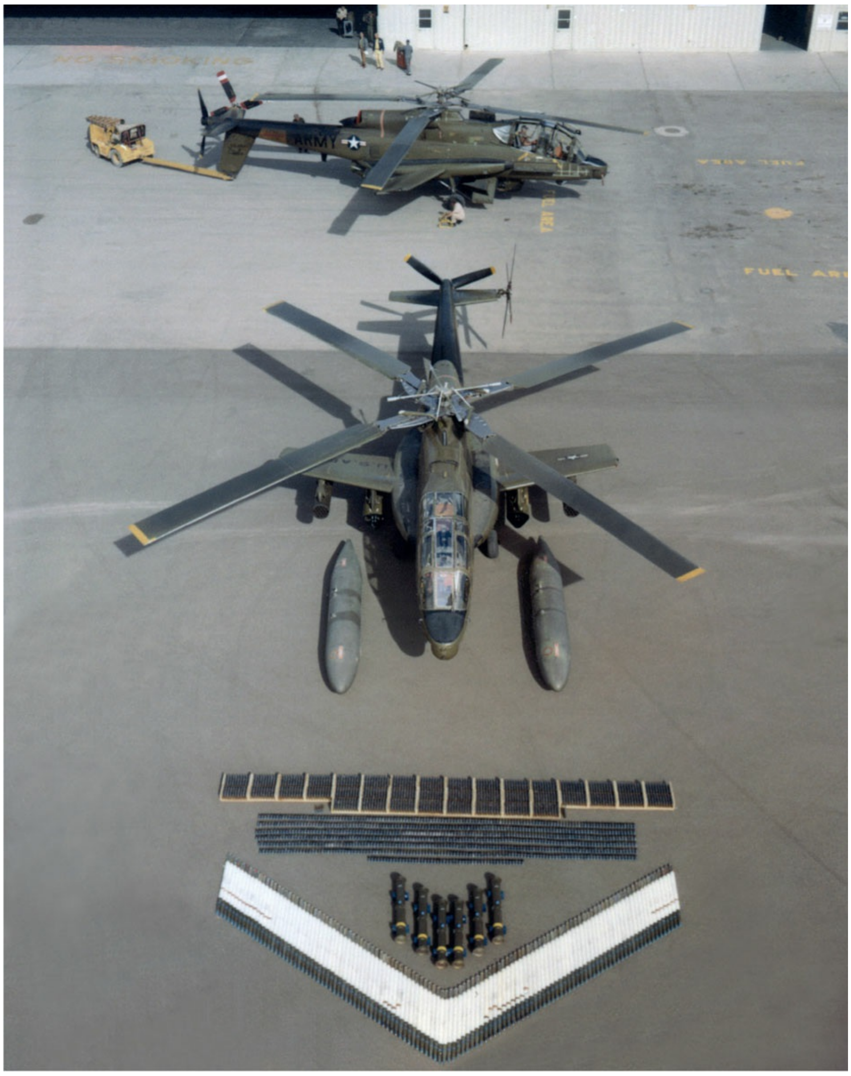
The fate of the tenth and final AH-56A after the failure of its main rotor blades during a high stress and high torque test card. (Lockheed Martin)



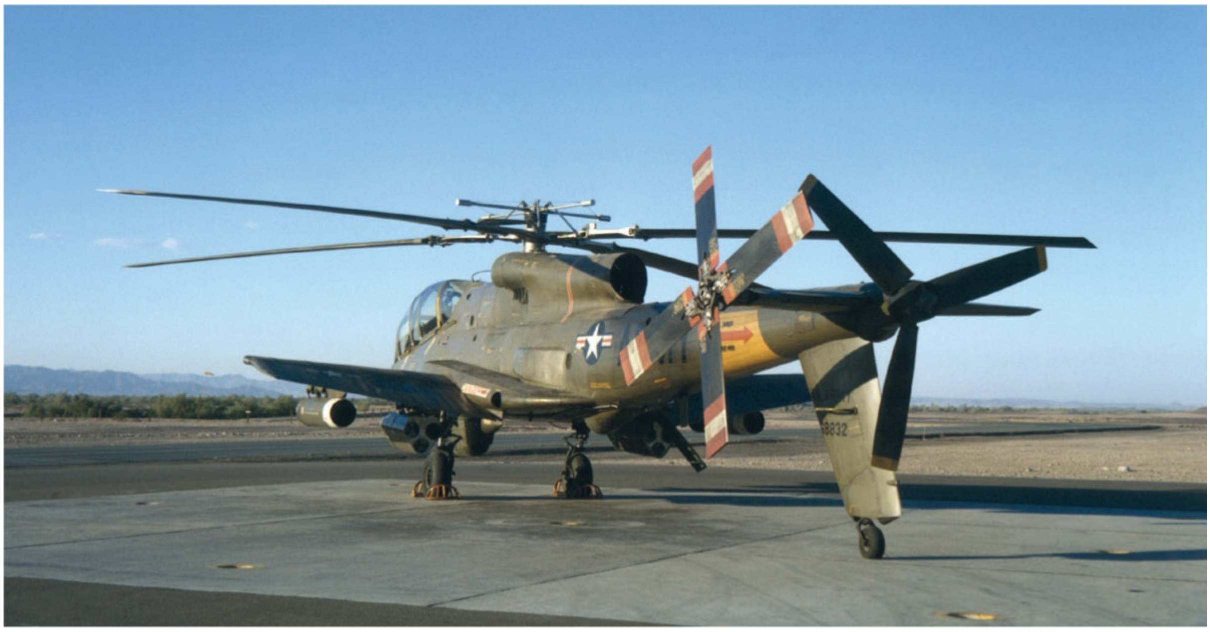
The pilot's rear cockpit of the AH-56A Cheyenne. Fairly standard layout with a moving map display in front of the control stick. (Lockheed Martin)



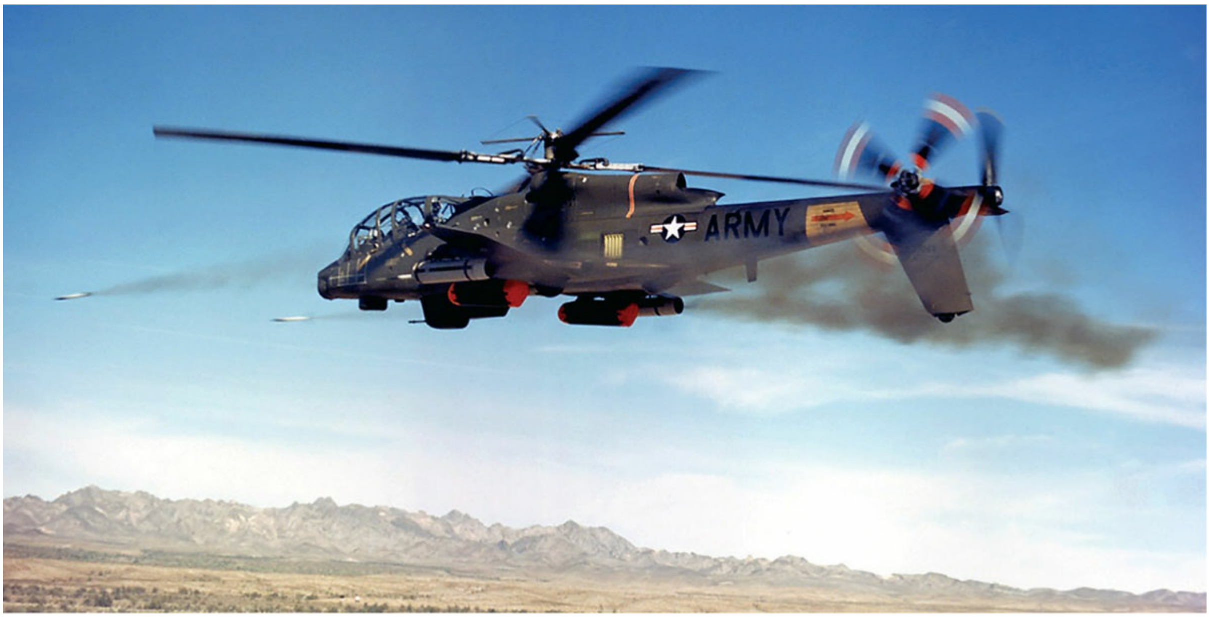
The forward weapons operator cockpit of the AH-56A, showing the gun turret control stick to the left and just below the optical viewing eyes piece with the weapons selection panel between the legs of the weapons operator. Also viable in this photo is the very early "heads up" eye piece in the light gray structure on the upper right-hand side of the instrument panel. (Lockheed Martin)



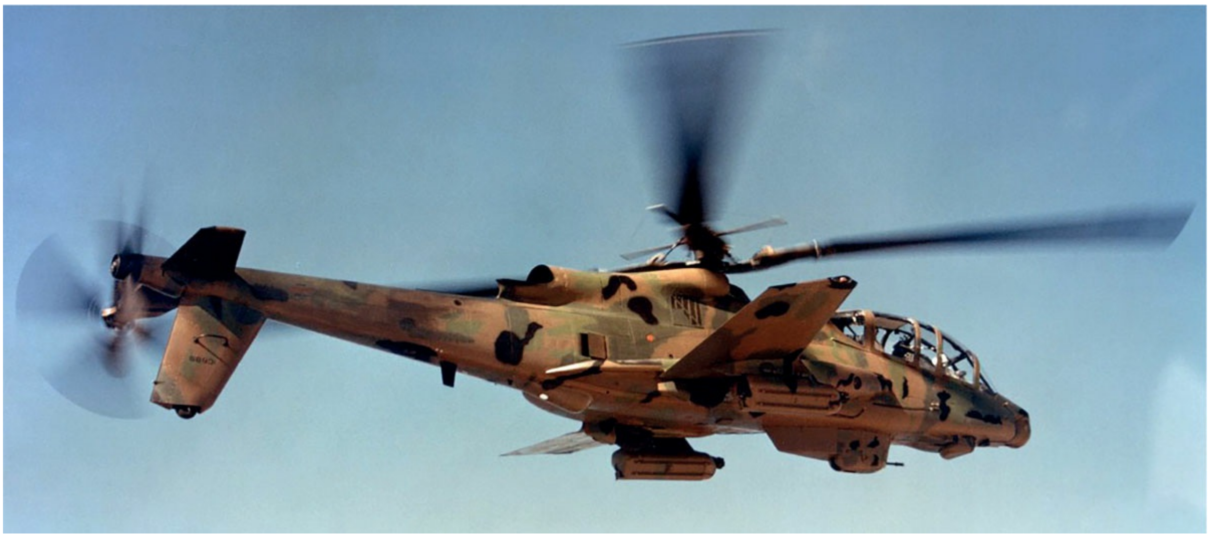
Parked in front of the Lockheed hangar at Van Nuys Airport, the Cheyenne's weapons load is laid out in front of it. (Lockheed Martin)



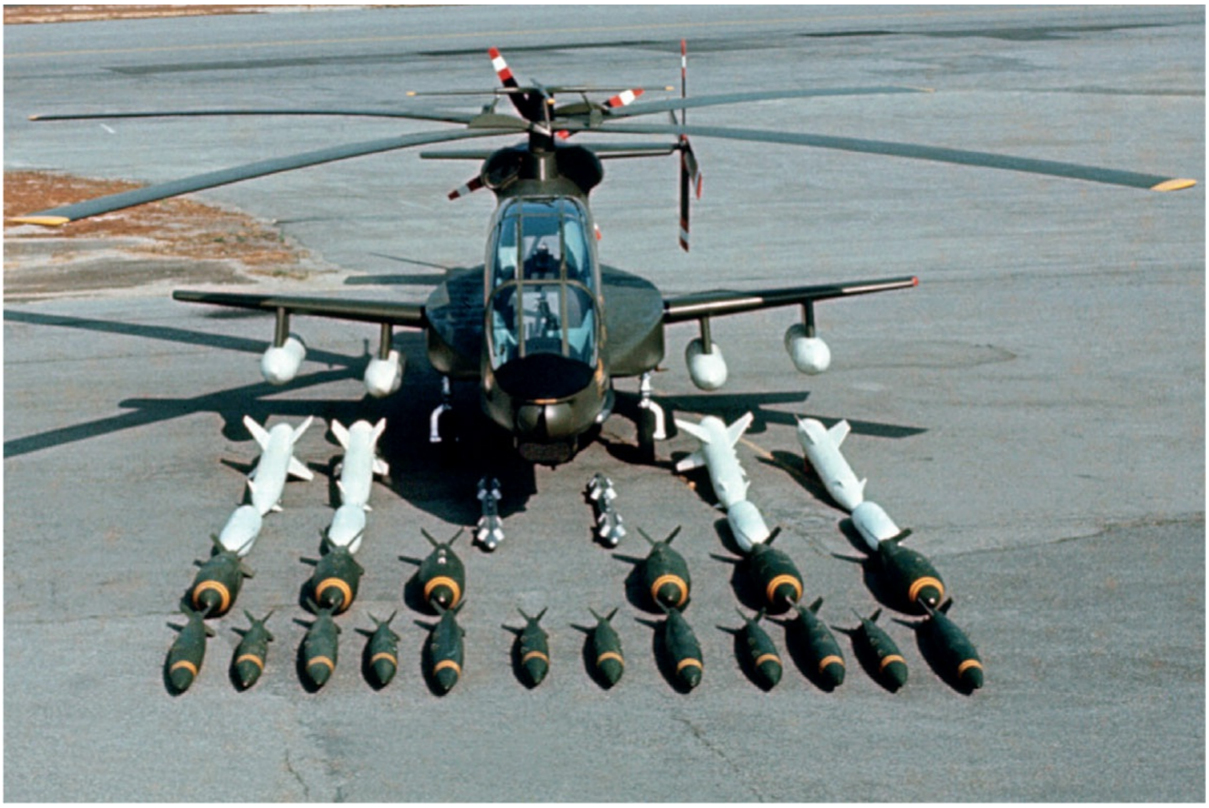
A three-quarter rear view of ship #1006 showing off its pusher propeller. (Lockheed Martin)



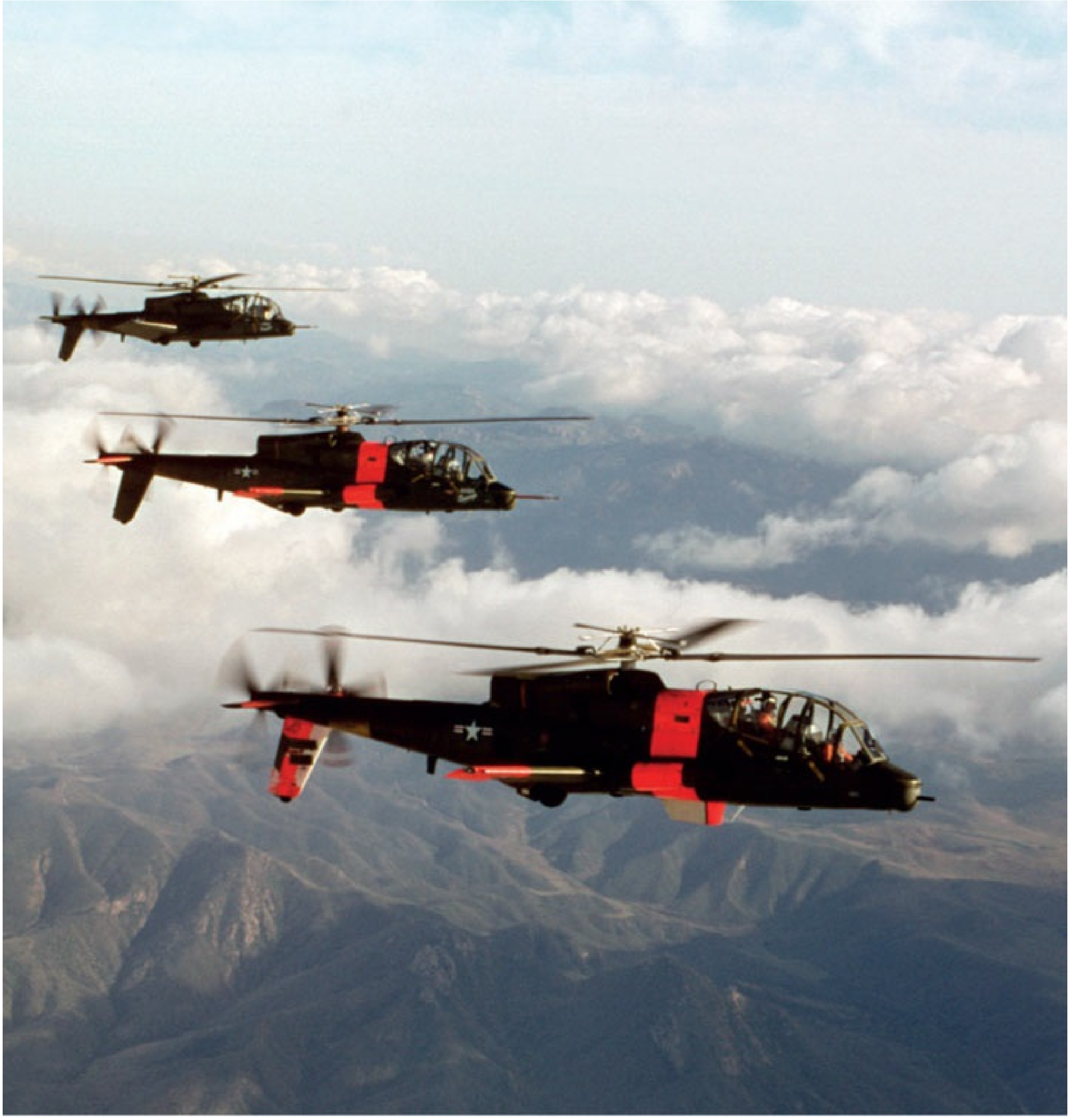
AH-56A ship #2006 fires its complement of 2.75in rockets from its outer wing weapons pylon. (Lockheed Martin)



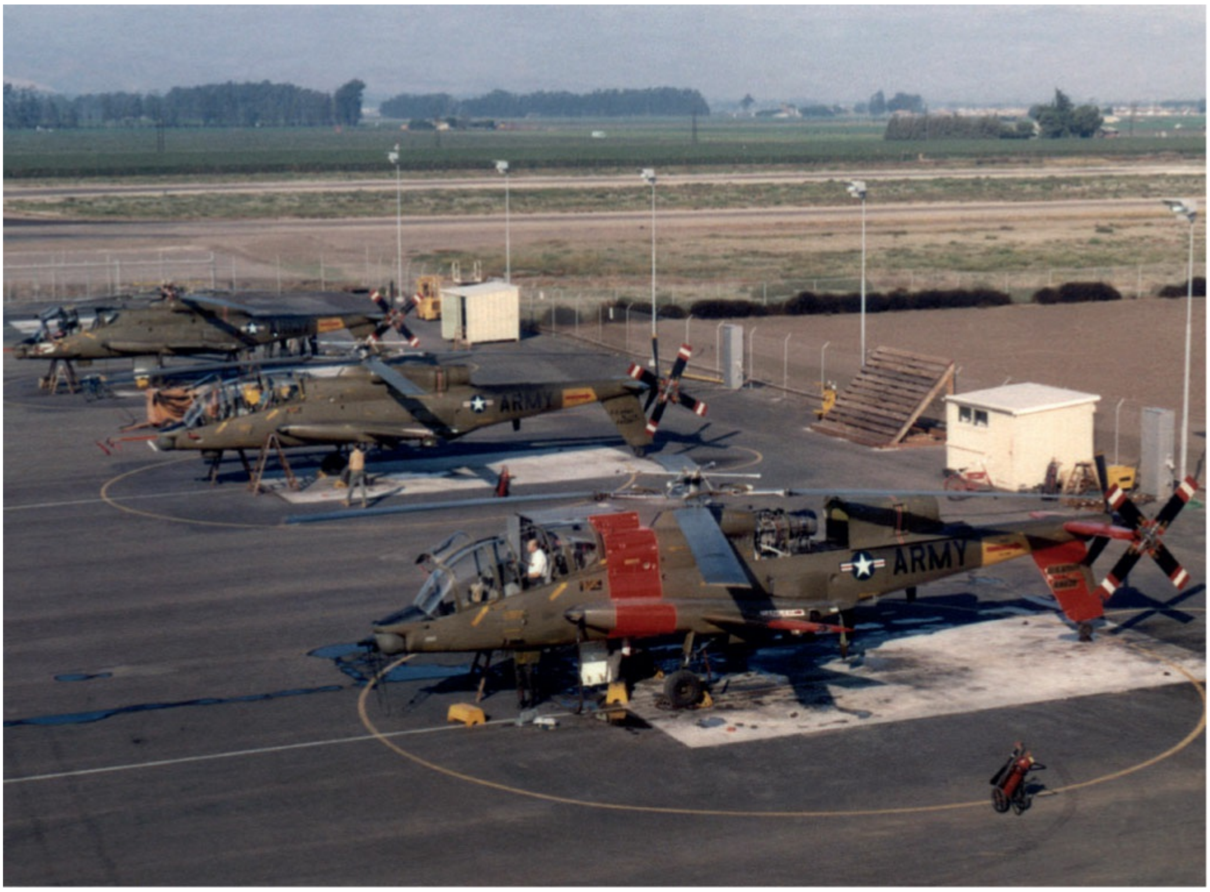
Later in ship #1006 flight-testing, the Army decided to change over the then-standard overall semi-gloss olive drab paint for the newer Vietnam three-tone jungle pattern. (Lockheed Martin)



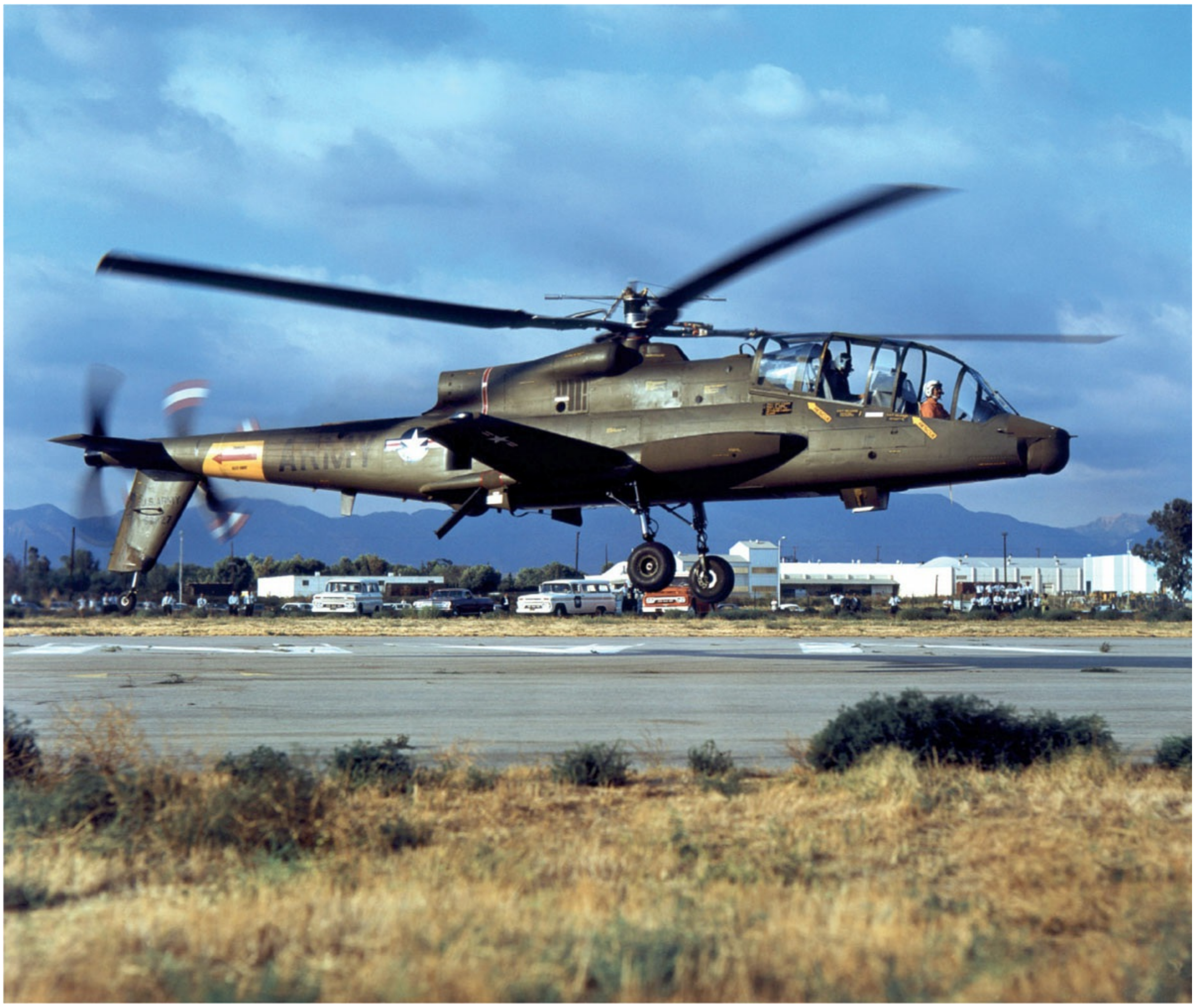
This shot shows the awesome array of weapons that the AH-56A was designed to carry. (Lockheed Martin)



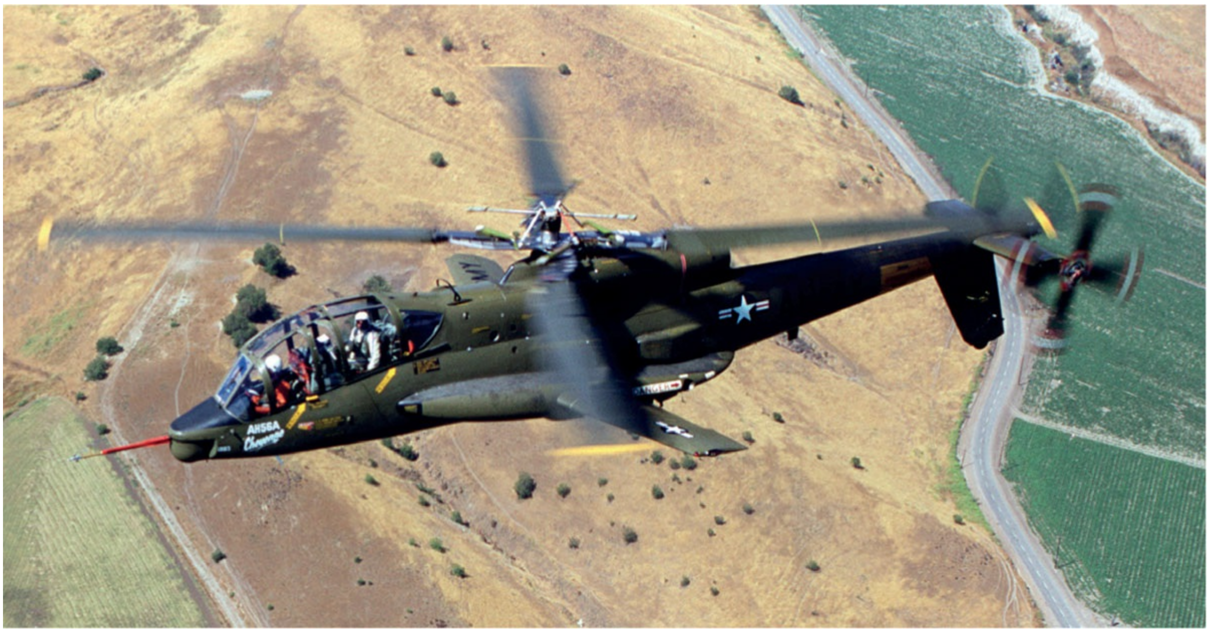
A formation of three AH-56 Cheyennes conducting flight-tests. (Lockheed Martin)



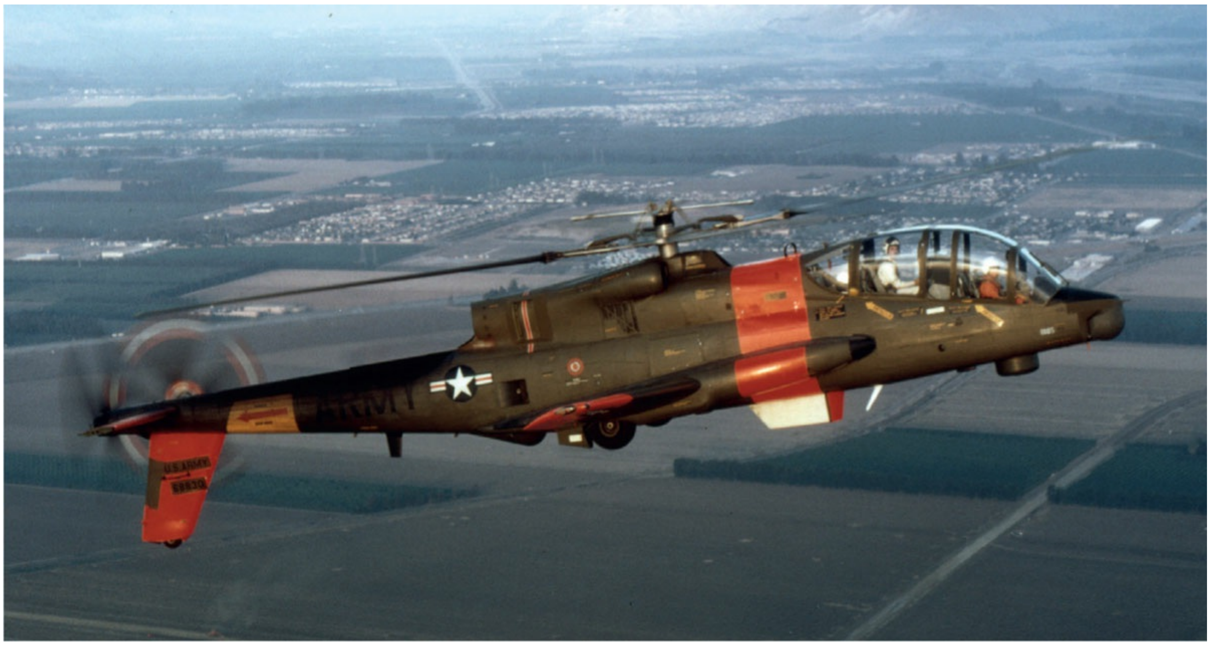
Three of the original complement of ten AH-56s are being preflighted for weapons release testing, flying out of the Oxnard County Airport north of Los Angeles. (Lockheed Martin)



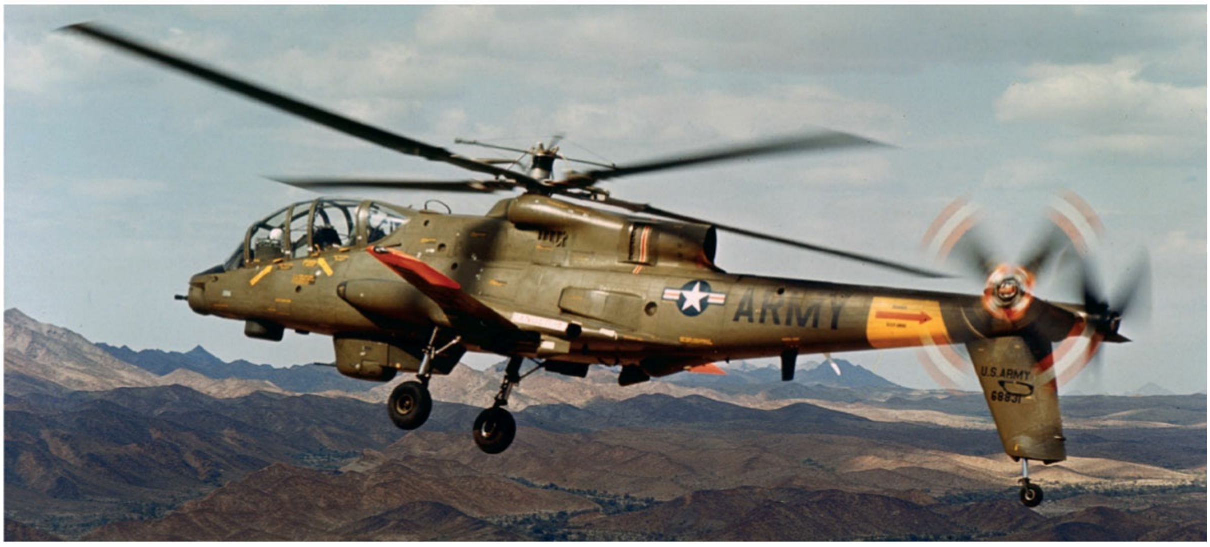
The first flight of the AH-56 was completed on 21 September 1967 using the second Cheyenne prototype, ship #1002, with test pilot Don Segner at the controls. (Lockheed Martin)



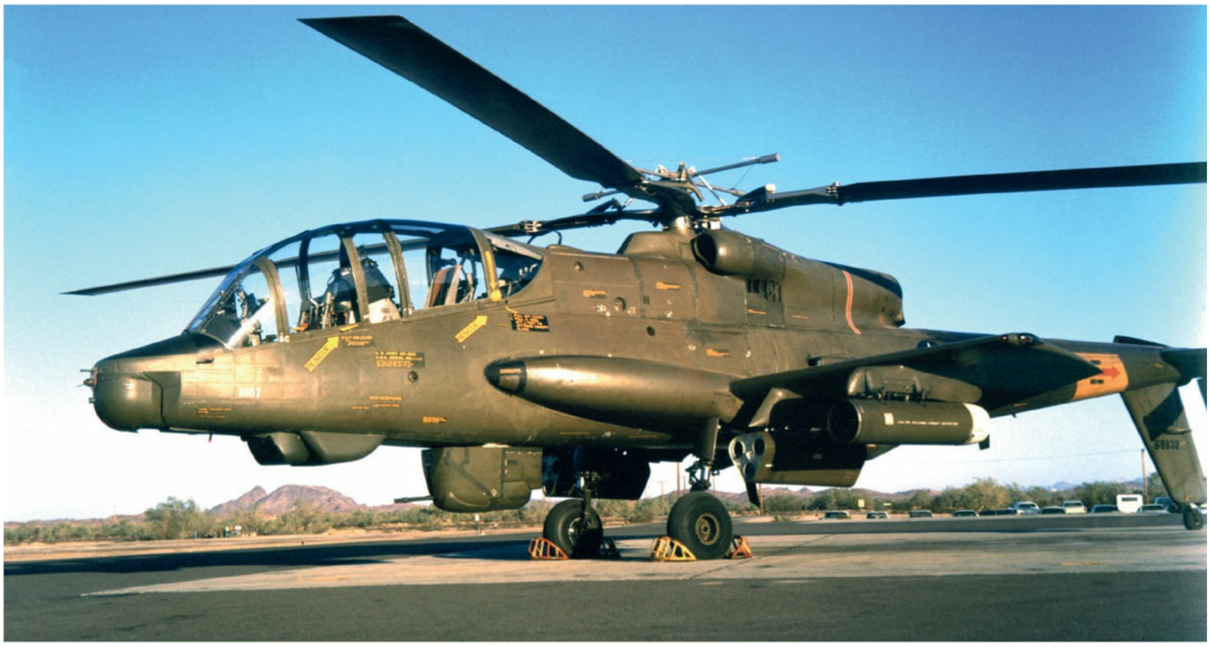
The AH-56 Cheyenne during a flight-test; its large stub wings and pusher propeller are clearly shown, as is the big greenhouse canopy over the tandem cockpit. (Lockheed Martin)



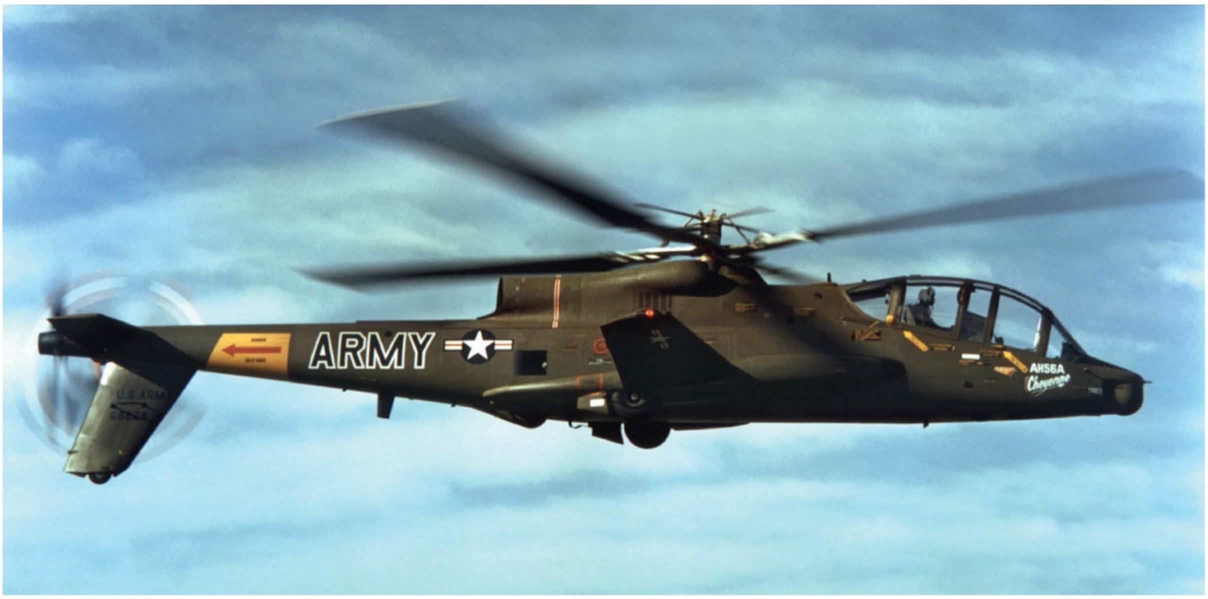
An early air-to-air view of ship #1005 sporting its very distinctive flight-test Day-Glo orange markings as it flies over the green fields of Ventura County near Oxnard, CA. (Lockheed Martin)



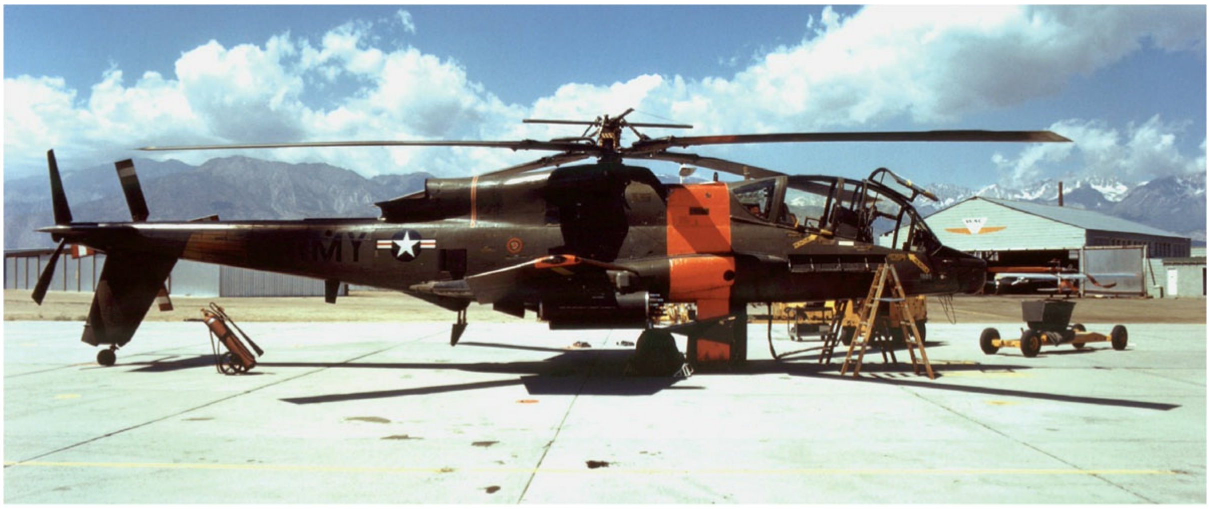
Usually when the AH-56A Cheyenne, in this case ship #1006, is airborne, the retractable landing gear is usually in the stowed position. (Lockheed Martin)



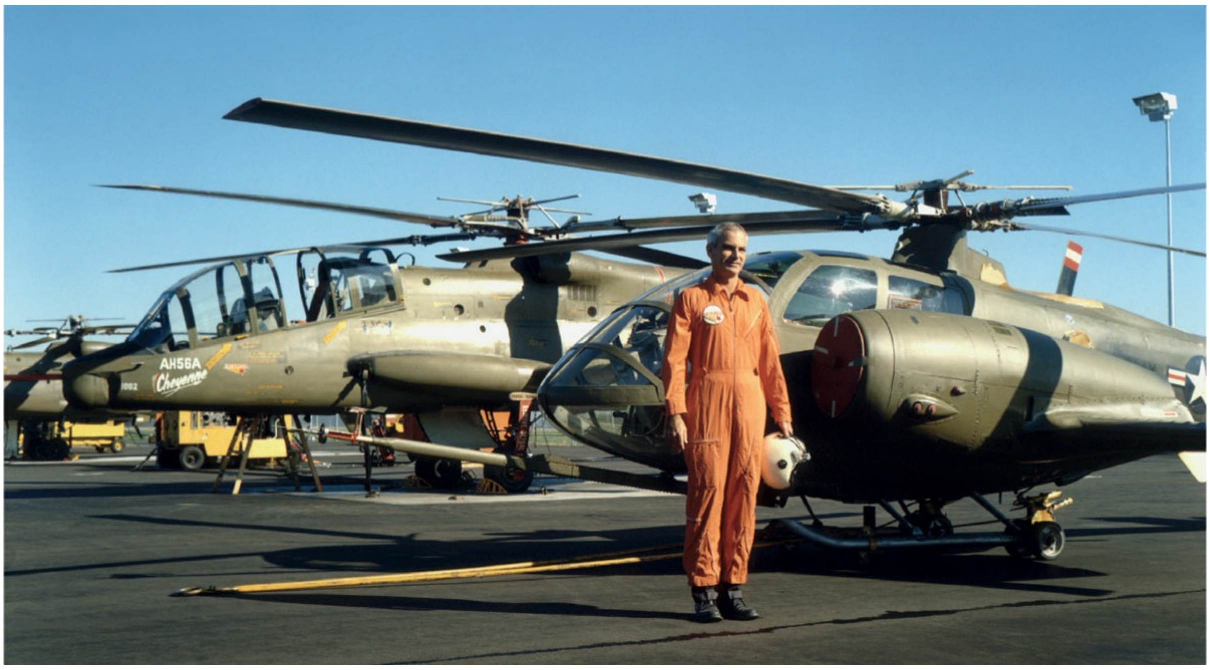
Along with its fellow AH-56As, ship #1007 shows the belly-mounted XM-140 30mm cannon installation and the 19 x 2.75in rocket pods carried on the outer wing pylons. (Lockheed Martin)



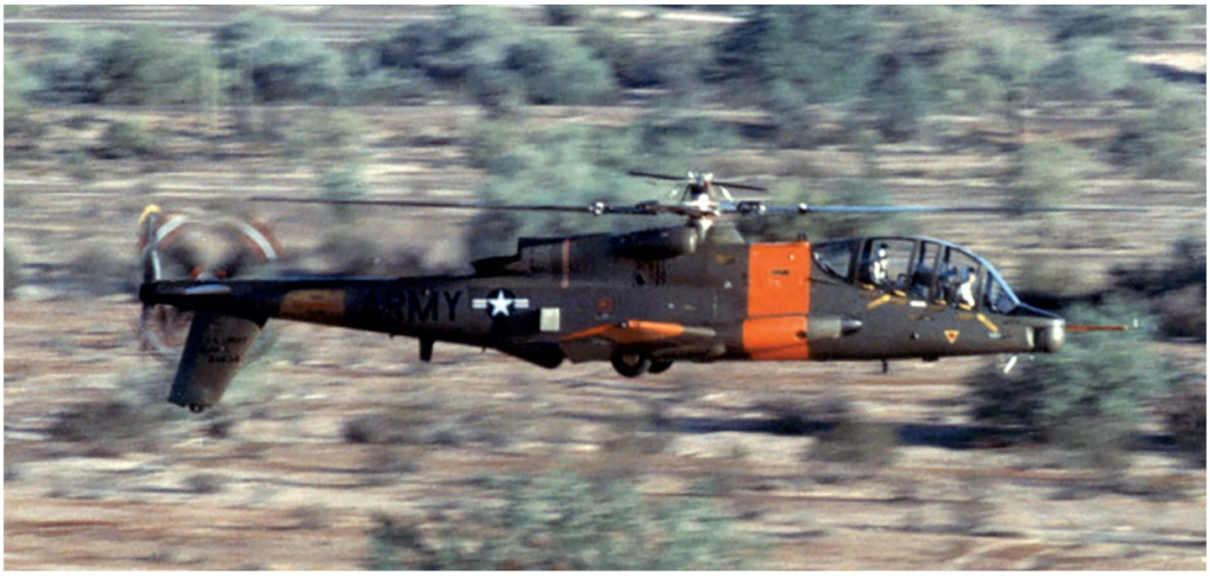
Ship #1003 flies without the nose-mounted gun or weapons pylons installed, showing off its very clean lines. (Lockheed Martin)



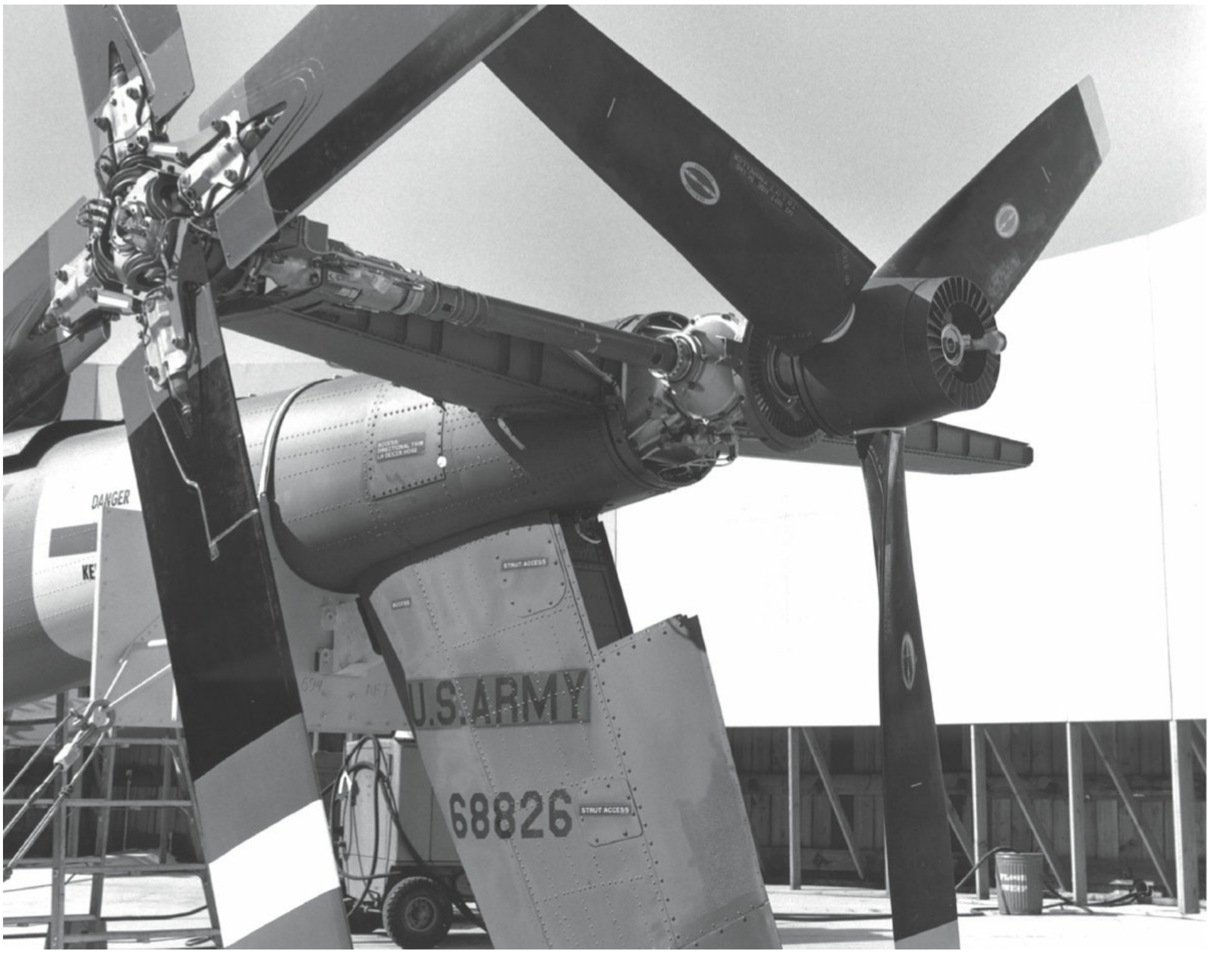
On the ramp of Oxnard County Airport is the last flyable AH-56A, ship #1009, as ship #1010 was destroyed in a blade separation accident during rotor testing at "Fort Cheyenne." (Lockheed Martin)



Lockheed test pilot Ray Goudey stands in front of a Lockheed XH-51A rigid-rotor helicopter, with AH-56A ship #1002 in the background, as both types were flight-tested out of Van Nuys Airport. (Lockheed Martin)



AH-56A ship #1005 is seen flying at very high speed just above the treetops along the Coast Mountain foothills just north of Santa Barbara, CA. (Author's collection)


DANGER
U.S.ARMY
68826
STRUT ACCESS

Closeup detail of the rear tail rotors employed on the AH-56A Cheyenne. The rear pusher rotor is used for high speed. (Author's collection)

LOCKHEED
ARMY
AH56A
Cheyenne
1010
BUNKER

US Army Lt Gen William B. Bunker was there for the 3 May 1967 roll out of the first AH-56A. (Lockheed Martin)

Standing in front of the AH-56A Cheyenne are two of the three test pilots, Donald R. Segner and Col Emil "Jack" Kluever. Not in the photo is Ray Goudey. (Lockheed Martin)

RESCUE
EXIT RELEASE
EXIT RELEASE
RESCUE
1006

Kneeling under ship #1006 is Lockheed test pilot Donald R. Segner. By the time of his retirement from Lockheed, Segner had over 55 years of aviation and transportation-related experience in operational, flight-testing, aircraft design and development under his belt. (Lockheed Martin)

AH56A
Cheyenne
1002
LOCKHEED
CONTROLS ACCESS
7.62MM CARTRIDGE DRIVE ACCESS
BATTERY DISCONNECT INSIDE
SERVICE THRU BOTTOM PANEL
BATTERY VENT
INTERCOM RECP INSIDE

Standing proudly in front of AH-56A ship #1002 is one of the three primary test pilots for the Cheyenne, senior helicopter test pilot Col Emil "Jack" Kluever. (Lockheed Martin)

U-2R DRAGON LADY

1967

PROGRAM: U-2R/S

Name: Dragon Lady

Mission: Strategic reconnaissance

Length: 63ft (19.2m)

Wing Span: 103ft 3in (31.47m)

Height: 16ft (4.87m)

Max T.O. Weight: 40,000lb (18,000kg)

First Flight: 28 August 1967

Last Flight: Still operational through at least 2026

Crew: 1; 2 in the TU-2R/S

Number Built: 48

Power Plant: 1 x General Electric F118-GE-101

Design Speed: Mach 0.54 (410mph; 660km/h)

Service Ceiling: 76,250ft (23,241m)

Combat Radius: < 7,000 miles (6,080nm; 11,265km)

Weapons Load: 5,000lb (2,270kg) of cameras and sensors

U-2R, or “Revised U-2,” is similar to its older siblings, the U-2A/G, as it is a single-seat, high-altitude jet aircraft flown by the Air Force for intelligence gathering, surveillance and reconnaissance. Perhaps the most famous spy plane ever built, the U-2, also known as the Dragon Lady, has been in service since 1956. The prototype flew in 1955, and the last plane in the series was built in 1989.

At first the plane was used by the CIA and the USAF to monitor electronic emissions, to sample the upper atmosphere for evidence of nuclear weapons tests, and to photograph sites deep within the territory of the former Soviet Union, China and other Cold War enemies. Strategic intelligence-gathering missions have continued, but the U-2 has also been used for battlefield reconnaissance and surveillance in numerous conflicts and tension spots where the United States has been engaged since the Vietnam War in the 1960s.

Over its long service life, the U-2 has periodically faced competition from other intelligence-gathering systems (for instance, Earth-orbiting satellites or the Mach 3+ SR-71 Blackbird spy plane), but intelligence and military services consistently have found it useful because of its operational flexibility, excellent aerodynamic design and adaptable airframe. In 2011 the Air Force indicated that the U-2 was scheduled for retirement from the USAF sometime after 2015, with many of its functions to be adopted by high-altitude long-endurance unmanned aerial vehicles (UAVs).

The U-2, designed by Kelly Johnson, is built of aluminum and limited to subsonic flight, and it can cruise for many hours above 70,000ft with a payload weighing as much as 3,000lb. Its exact operational specifications are secret. In the late 1960s the airframe was enlarged by more than one-third over the original structure, bringing the aircraft to a fuselage length of 63ft and a wing span of 103ft 3in. An array of systems for mapping and imaging terrain, detecting communication signals and performing a host of other intelligence-gathering and surveillance activities is installed in bays located in the aircraft’s nose, in the fuselage behind the pilot and in large pods located at mid-wing.

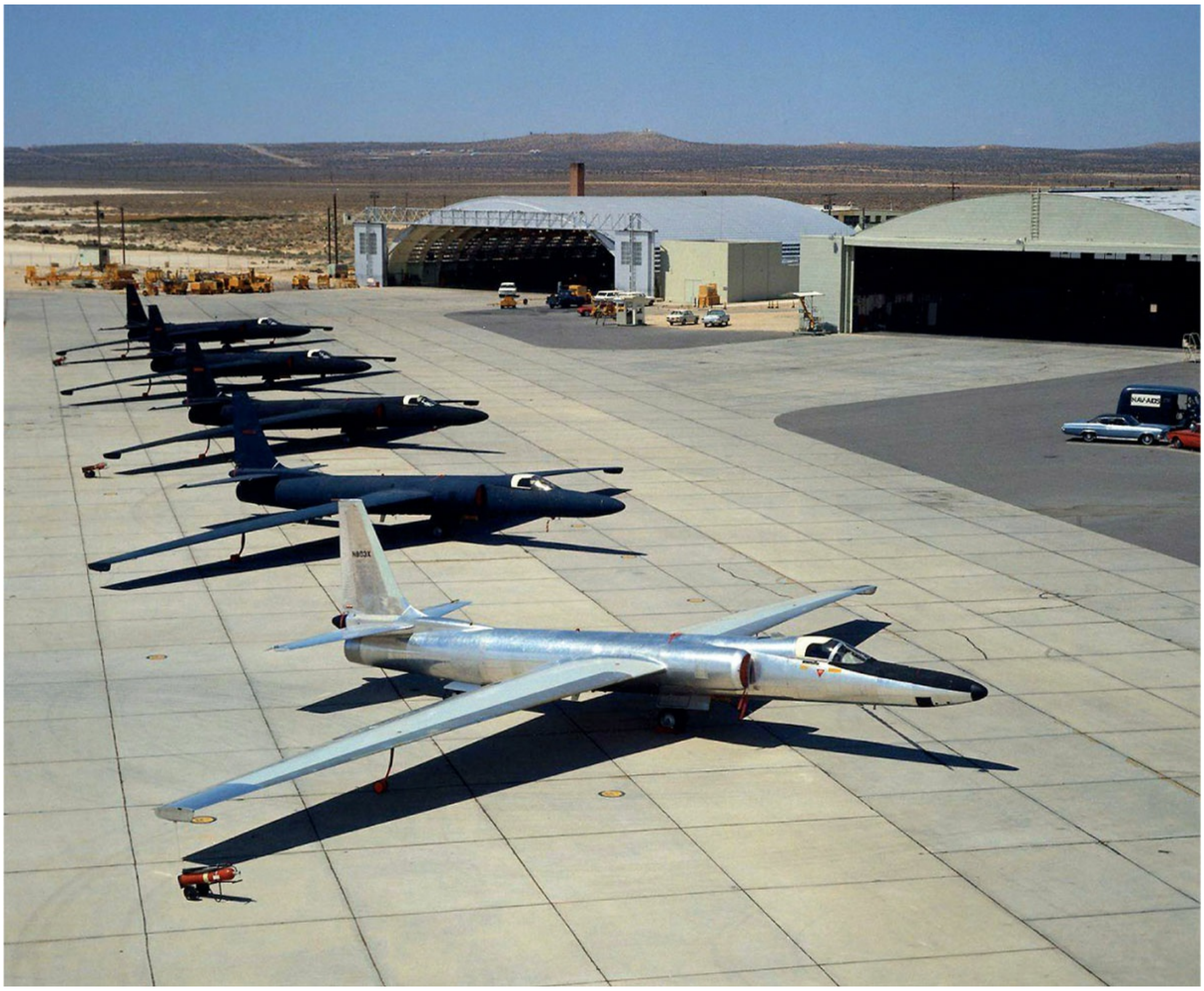
The U-2S, the newest variant of the U-2 family, is a single-seat, single-engine, high-altitude reconnaissance and surveillance aircraft providing signals, imagery, and electronic measurements and signature intelligence, or MASINT. The U-2 is capable of gathering a variety of imagery, including multi-spectral electro-optic, infrared and synthetic aperture radar products which can be stored or sent to ground exploitation centers. In addition, it also supports high-resolution, broad-area synoptic coverage provided by the optical bar camera producing traditional film products which are developed and analyzed after landing.

The U-2 also carries a signals intelligence payload. All intelligence products except for wet film can be transmitted in near real-time anywhere in the world via air-to-ground or air-to-satellite data links, rapidly providing critical information to combatant commanders. MASINT provides indications of recent activity in areas of interest and reveals efforts to conceal the placement or true nature of man-made objects.

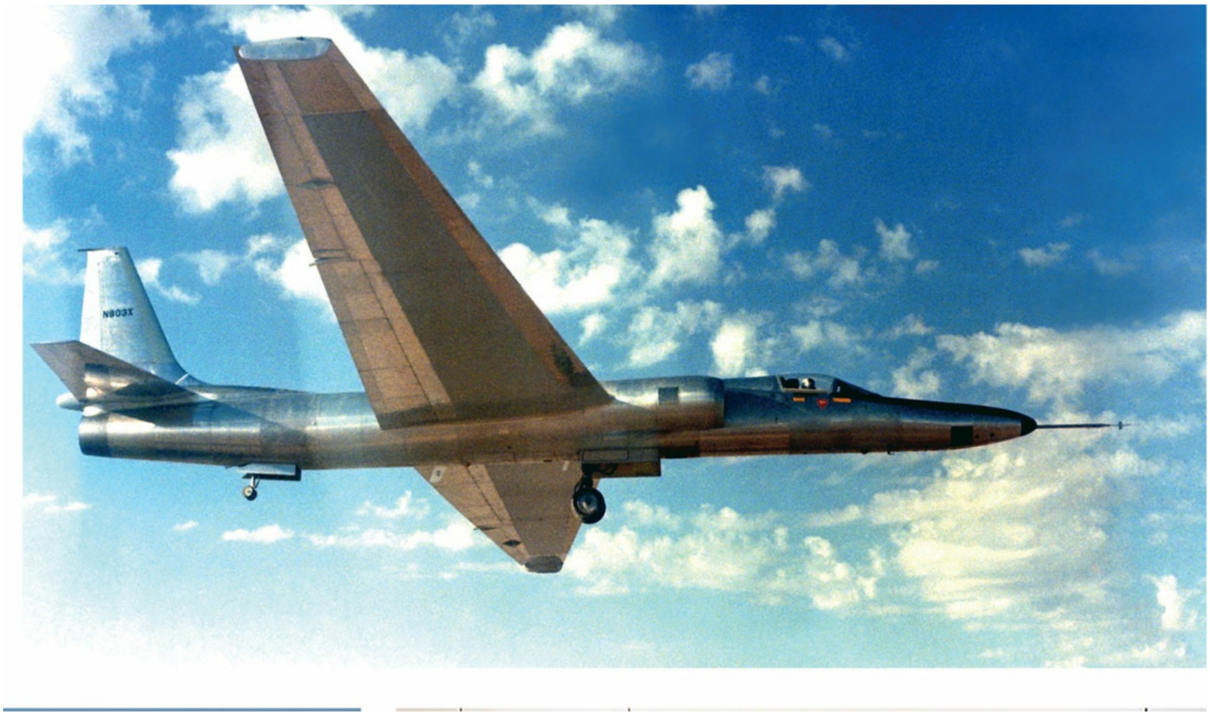
As the U-2 is routinely flown at altitudes of just over 70,000ft, its pilot must wear a full pressure suit similar to those worn by astronauts. The low-altitude handling characteristics of the aircraft and bicycle-type landing gear require precise control inputs during landing; forward visibility is also limited due to the extended aircraft nose and "taildragger" configuration. A second U-2 pilot normally "chases" each landing in a high-performance vehicle, assisting the pilot by providing radio inputs for altitude and runway alignment. These characteristics combine to earn the U-2 a widely accepted title as the most difficult aircraft in the world to fly.

The current U-2S is powered by a lightweight, fuel-efficient General Electric F118-101 engine, which negates the need for air refueling on long duration missions. The U-2S Block 10 electrical system upgraded replaced legacy wiring with advanced fiber-optic technology and lowered the overall electronic noise signature to provide a quieter platform for the newest generation of sensors.

The U-2 Reliability and Maintainability program provided a complete redesign of the cockpit with digital color multi-function displays and up-front avionics controls to replace the 1960s-vintage round dial gauges which were no longer supportable.



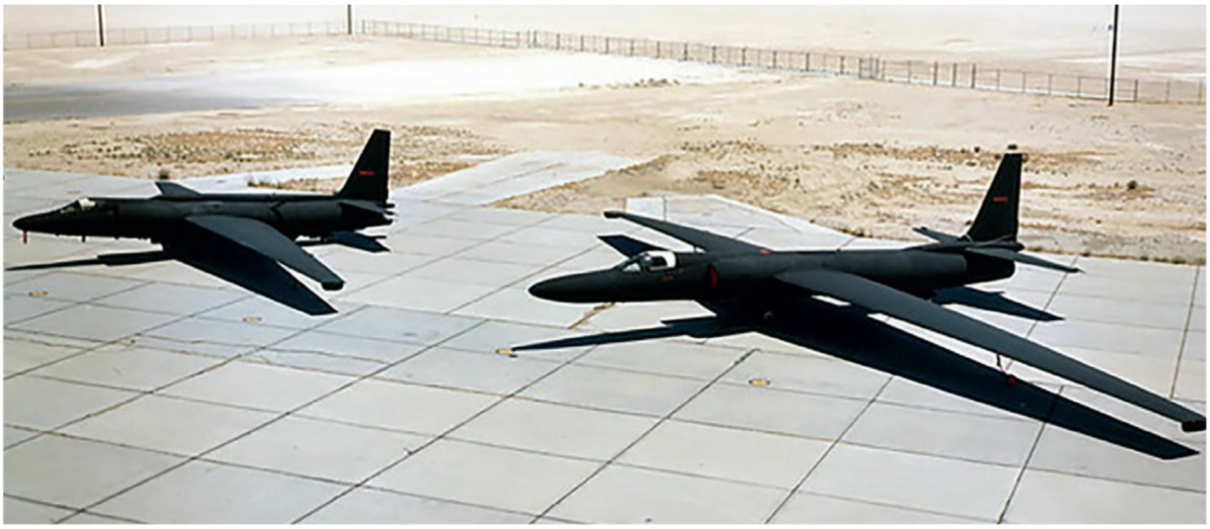
At the Agency's operating facility at Edwards North Base are the first five U-2Rs taken several months after the U-2R's first flight in August 1967. (Author's collection)



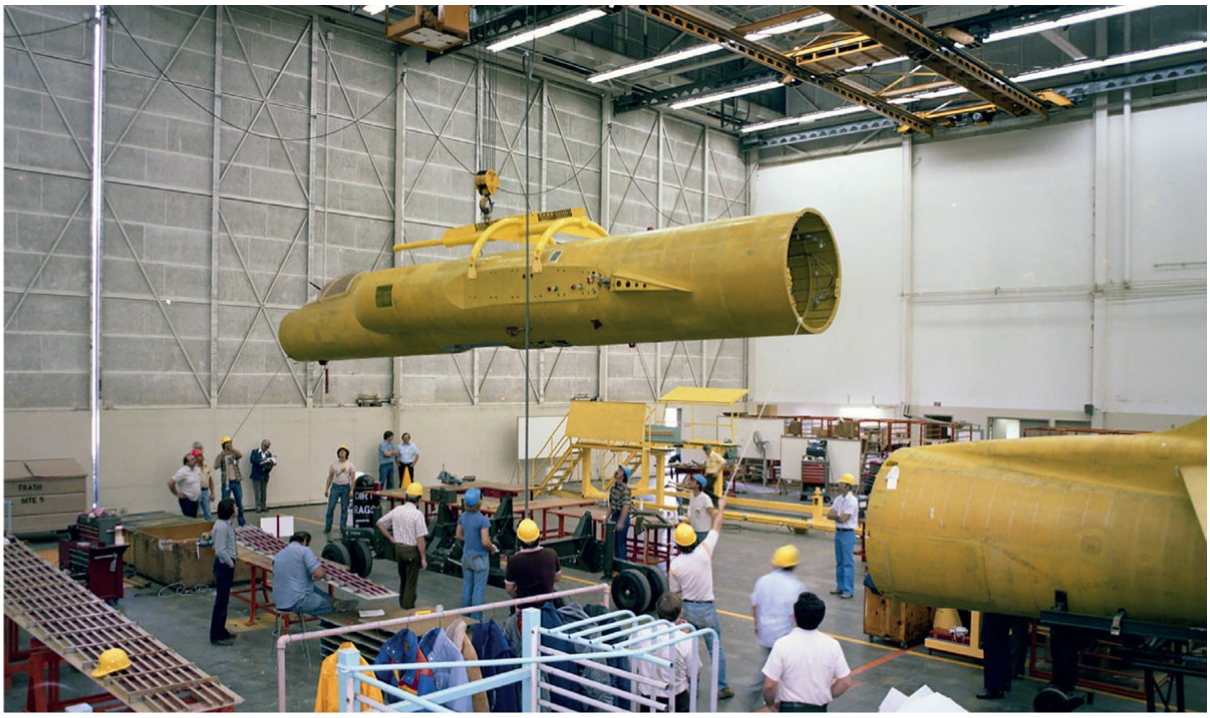
The first U-2R, with civil registration of N803X, takes to the air for the first time on 28 August 1967 following the takeoff from Edwards North Base. Lockheed's chief test pilot, Bill Park, is at the controls. (Author's collection)

CANOPY HERE
2R
2R

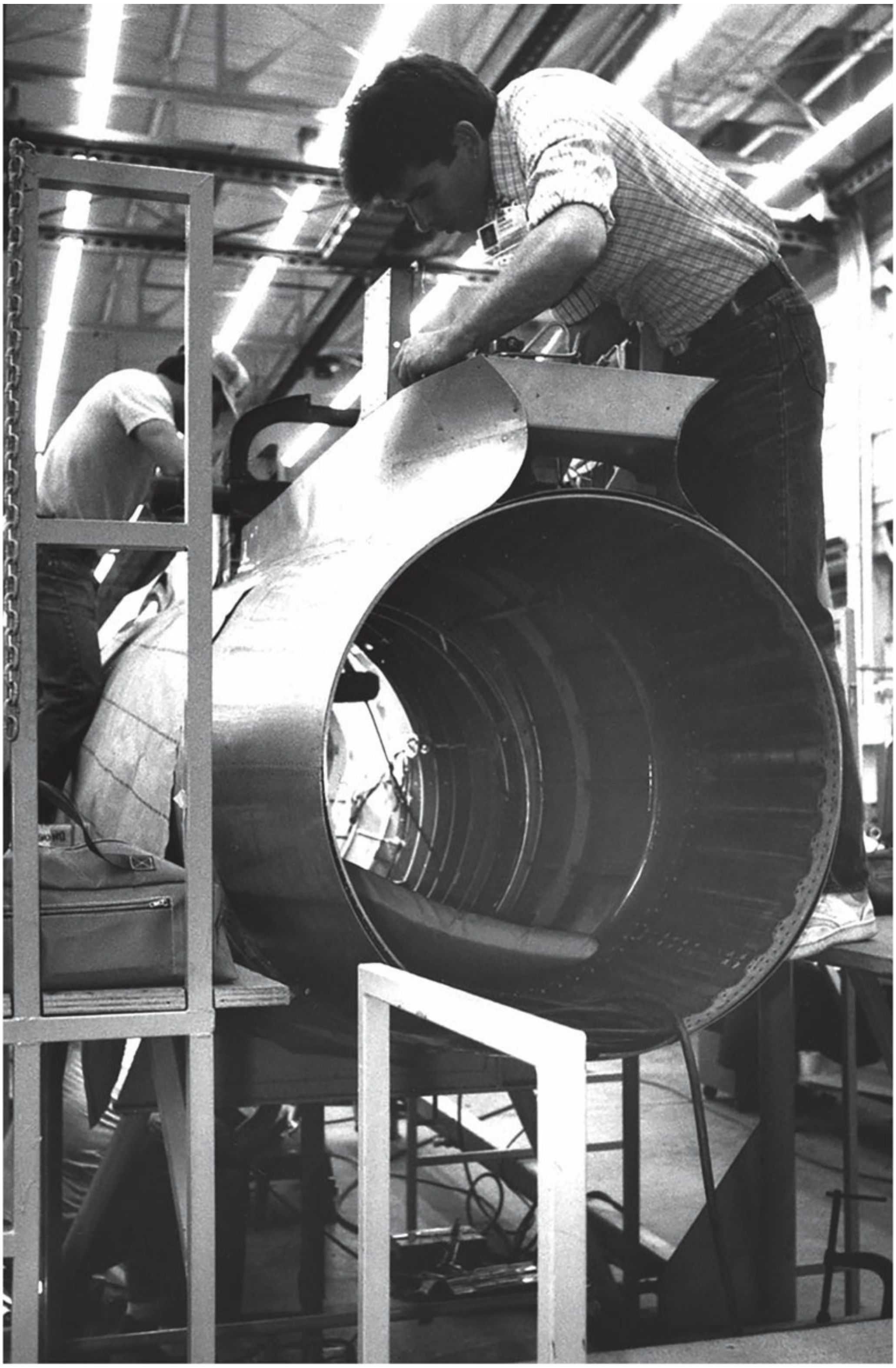
Bill Park, completes his preflight checklist prior to the first flight of the "new" U-2R. (Author's collection)



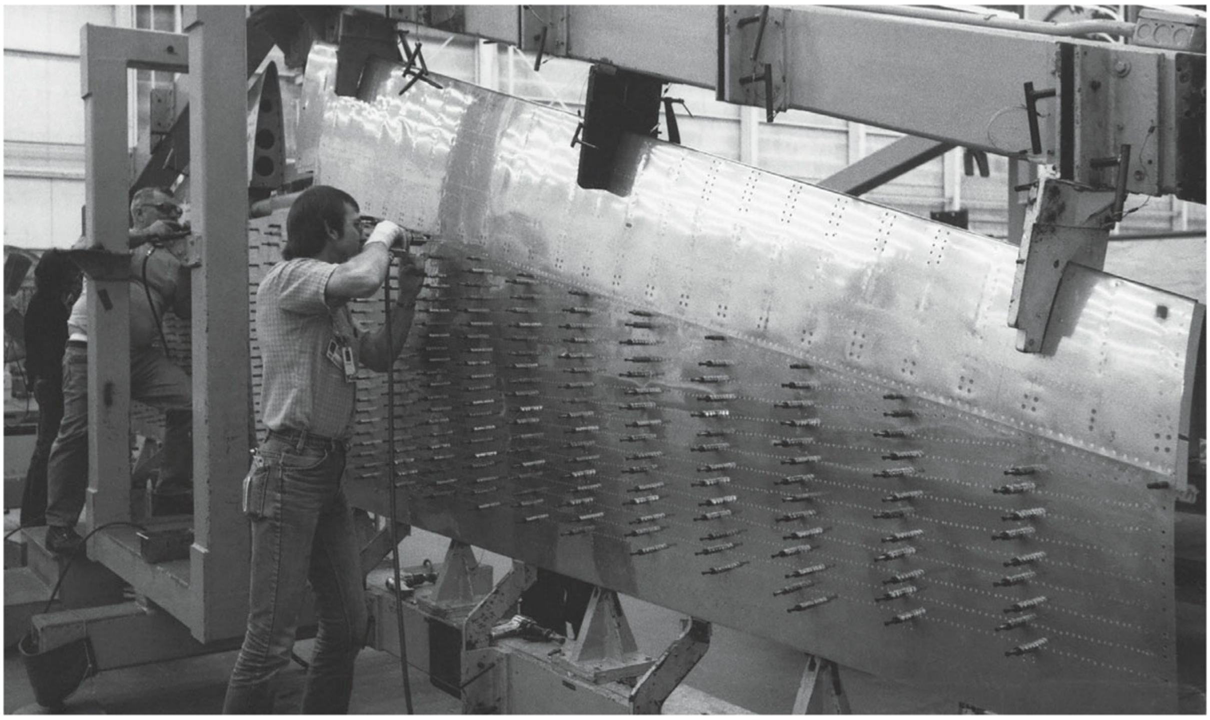
Bringing in the new and out with the old. Two aircraft with the same designation couldn't be more different. (Author's collection)



TR-1A production, while still at the Burbank location prior to moving production to Palmdale and Air Force Plant 42, Site 7. The TR-1 designation was a more politically correct name for the U-2R. It was changed back to U-2R once the production run was completed. (Lockheed Martin)



At the TR-1A/U-2R production site, a Lockheed craftsman checks out the aft fuselage of the newly built TR-1/U-2R. (Lockheed Martin)



U-2R wing nearing final assembly. The wing is what is called a "wet" wing as it was designed from the outset as a fuel tank. (Lockheed Martin)

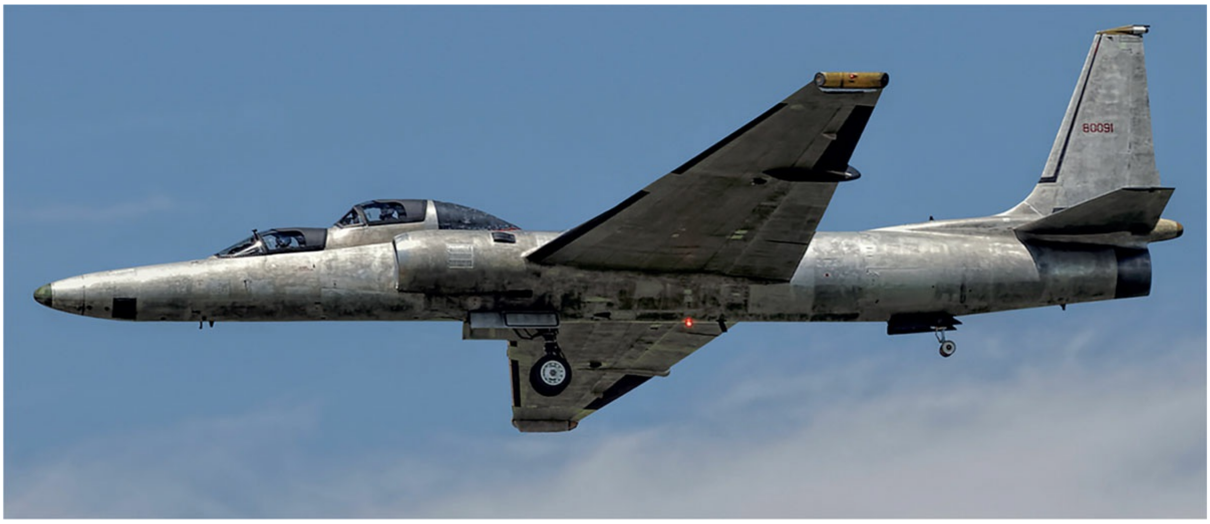
On 9 September 1967, the first U-2R, with Bill Park at the controls, takes to the air for the very first time. (EAFB/HO)

From the camera of Jim Mumaw is this colorful two-tone shot of a NASA ER-2A (the same as the U-2R/TR-1A, it is a different name for the same aircraft) taken on 14 April 2011 on approach to Air Force Plant 42 in Palmdale. (Jim Mumaw)

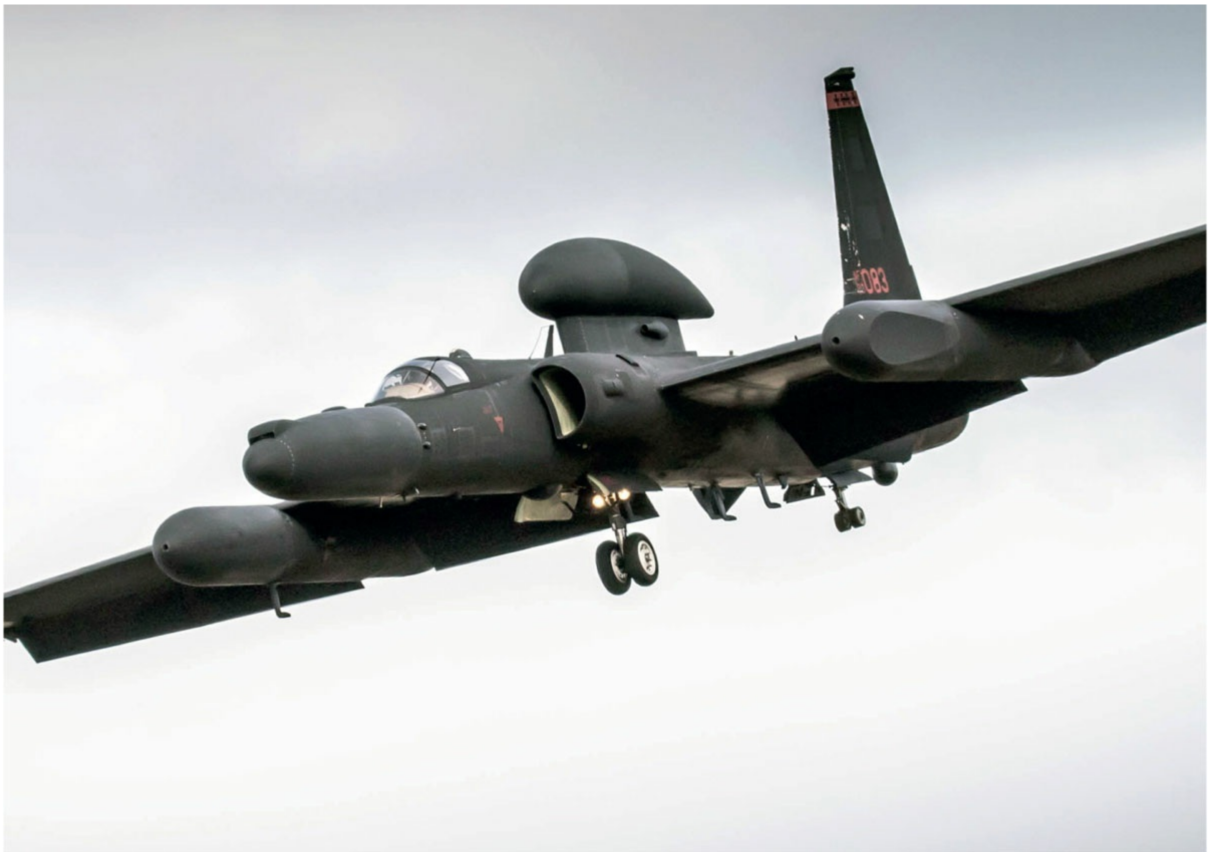
The initial U-2R on the ramp at North Base just prior to being towed on to the Rogers Dry Lake for its first ever flight. (EAFB/HO)

The first U-2R is being pulled out of its dedicated hangar at Edwards North Base complex. This location has always been for clandestine operations, such as the CIA's U-2 operations. (Author's collection)

This U-2S, 80-1071, is assigned to the 9th RW and was photographed on approach to runway 09 at RAF Fairford, Gloucestershire, England, in September 2019. (Si Blick)



Not many U-2 fans have had the fun of catching one without markings or paint. But this U-2ST was captured on 27 April 2019 on finals to Air Force Plant 42. (Jim Mumaw)



U-2S 80-1083 is on approach to runway 27 at RAF Fairford, Gloucestershire, England, in August 2017. (Si Blick)

Another shot of U-2S 80-1071/071 on final approach to runway 09 at RAF Fairford, Gloucestershire, England, in September 2019. (Si Blick)

The US Navy considered the U-2 for long-range open ocean coverage under the program to identify requirements for maritime surveillance aircraft with the U-2EPX. (Lockheed Martin)

Just being able to spot and track the movements of Russian warships and commercial vessels would have been a valuable intelligence tool. The EPX test aircraft seemed well suited to many of those requirements. (Lockheed Martin)

REMOVE BEFORE FLIGHT

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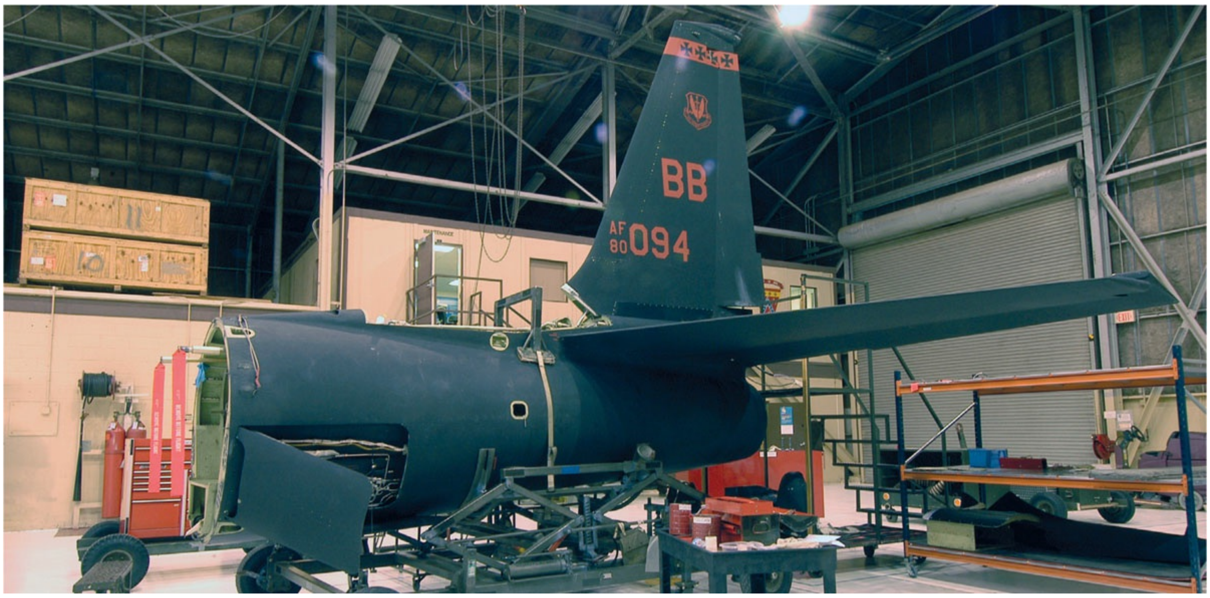
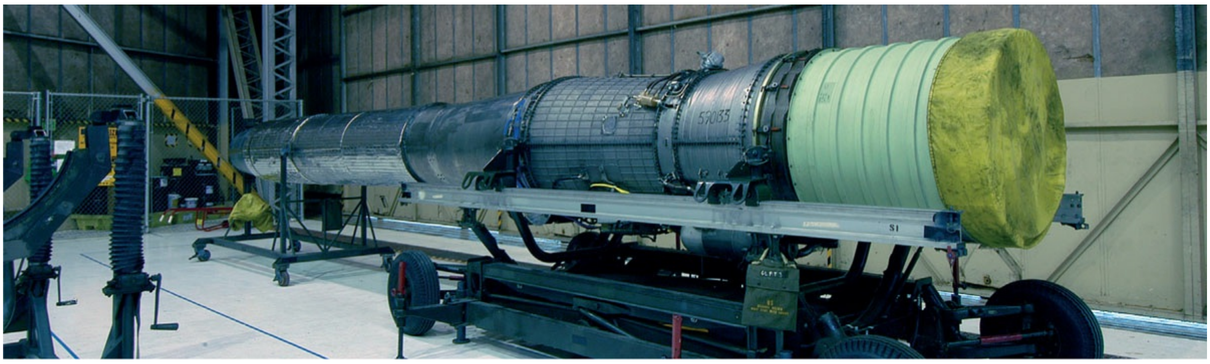
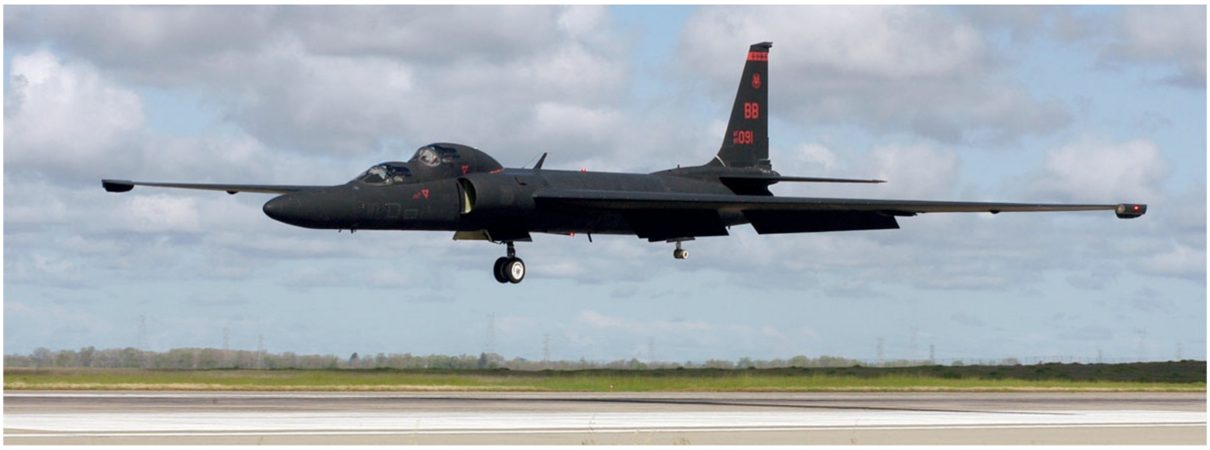
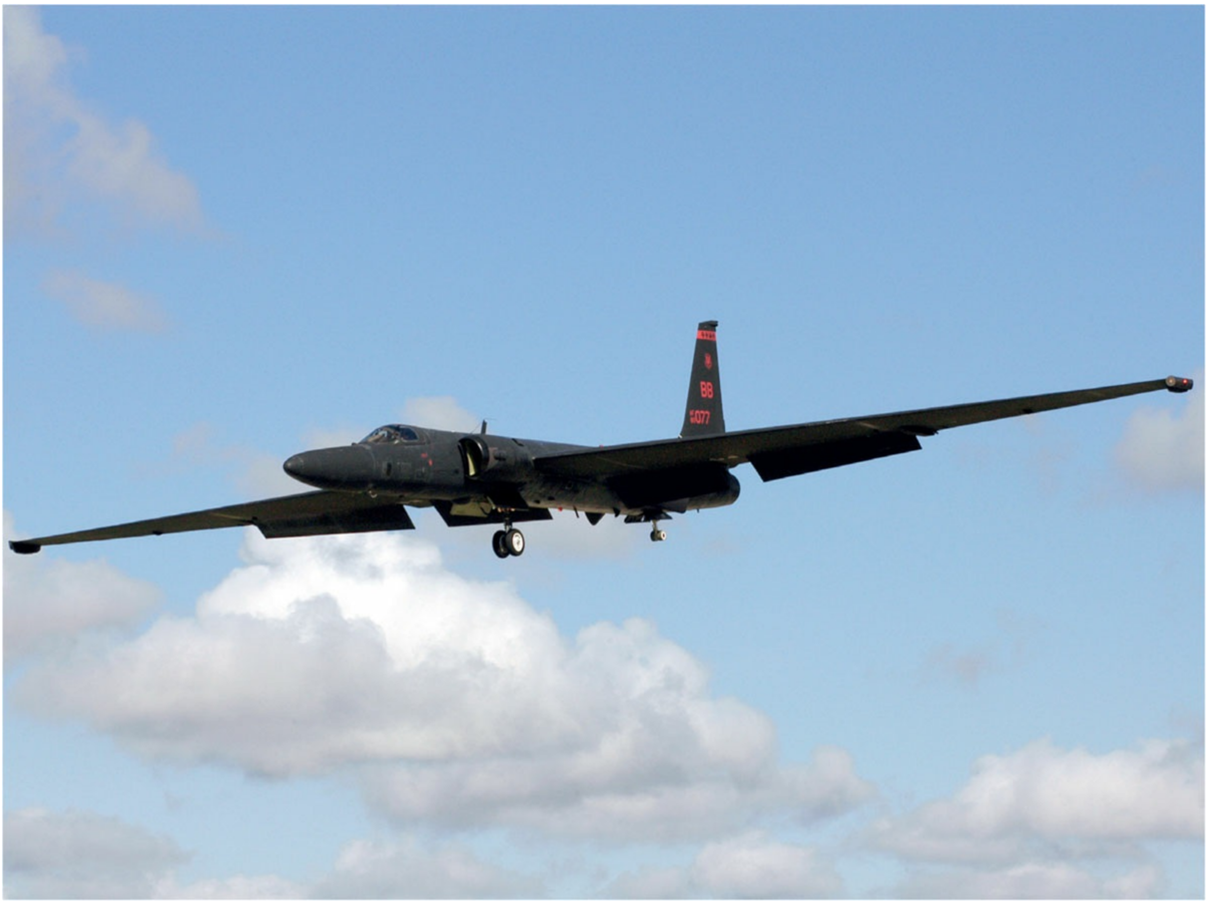




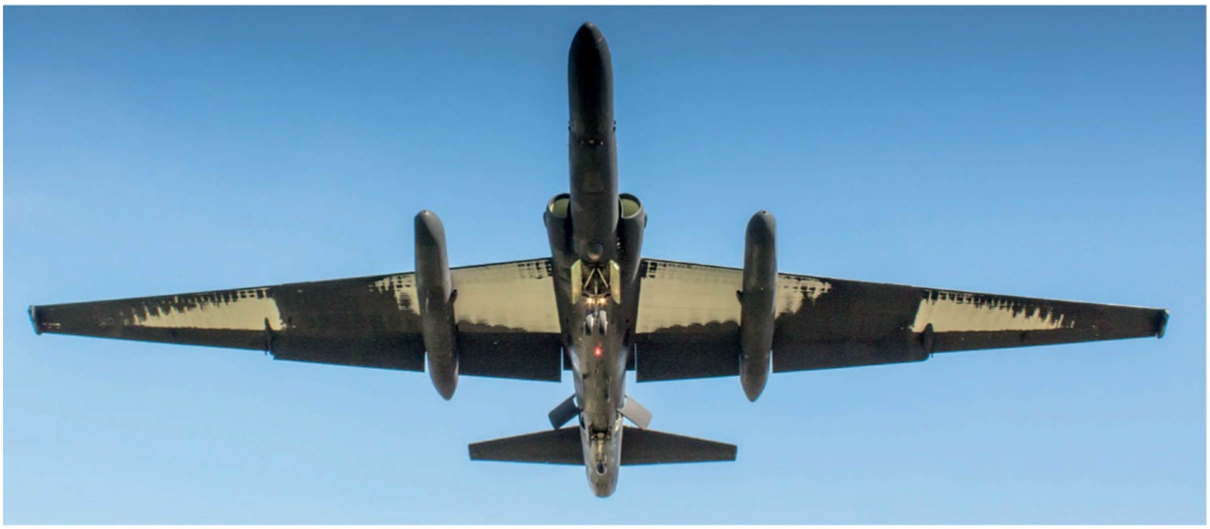
While doing a photo shoot of U-2S 80-1094/094 at Beale AFB on 17 April 2006, the author was given a photo tour of a U-2S undergoing a major phase dock tear down. What was unique about this photo session was seeing just how far apart the maintenance crews take their aircraft. Also interesting was that the General Electric F118-101 turbojet lacks many of the external plumbing and hydraulic lines seen on older jet engines. (James C. Goodall)



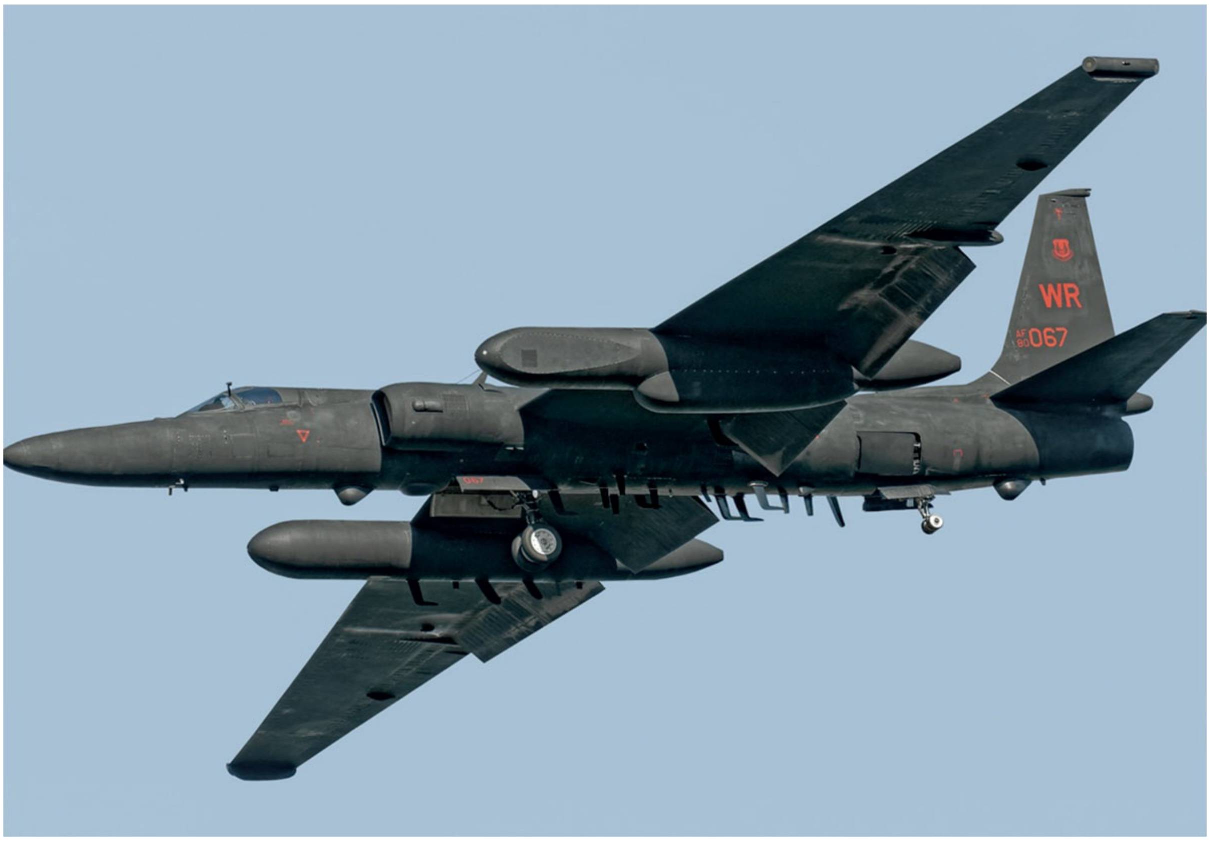
On the side of the runaway shooting U-2S and U-2ST's doing touch-and-goes on the 17 April 2006 photo session. Here, U-2ST 80-1091/091 comes in for a brief touch-and-go. (James C. Goodall)



During the same photo shoot, U-2S 80-1077/077 is captured on final approach to the Beale runway on 17 April 2006. (James C. Goodall)



U-2S 80-1083/083, complete with ice under wing on approach to runway 27 at RAF Fairford, Gloucestershire, England, in August 2017. (Si Blick)



U-2S 80-1067/067 carrying a WR tail code as it is assigned to the U-2S Systems Program Office (SPO) at Warner Robins AFB, but assigned full time to flight-test operations out of Air Force Plant 42, Site II. This is just another one of Jim Mumaw's great shots. (Jim Mumaw)

X-27 LANCER

1970

PROGRAM: X-27

Name: Lancer

Mission: Light Weight Fighter

Length: 53ft 2in (16.2m)

Wing Span: 28ft 7in (8.7m)

Height: 9ft 3in (2.82m)

Max T.O. Weight: 35,000lb (16,000kg)

First Flight: Mockup only

Crew: 1

Number Built: Mockup only

Power Plant: 1 x Pratt & Whitney TF-30-P-100 Turbofan

Design Speed: Mach 1.8 (1,477mph; 2,377km/h)

Service Ceiling: >60,000ft (>18,300m)

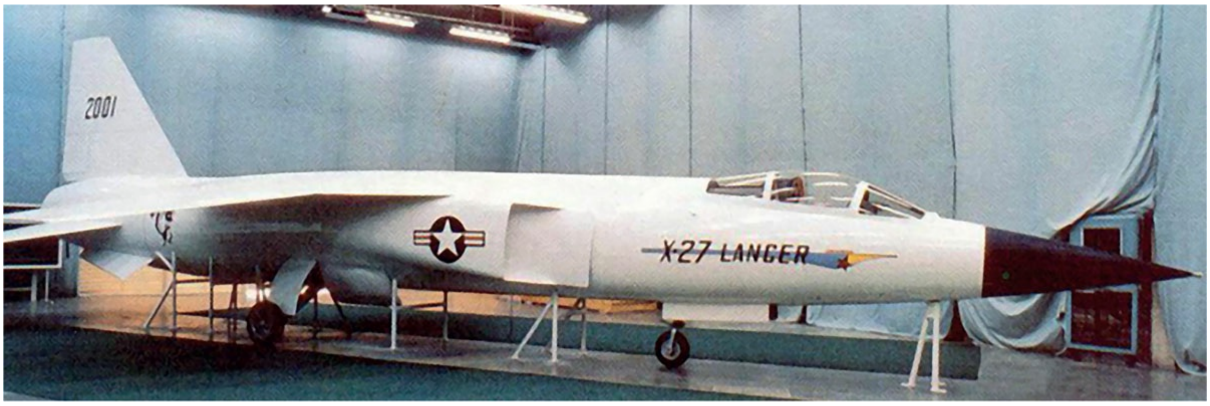
Combat Radius: 420 miles (365nm; 675.9km)

Weapons Load: 4,000lb (1,814kg)

The Lancer was proposed with the idea of using as many F-104 components as possible. This goal could be readily and quickly accomplished since the type was still in production in both Germany and Italy. A ready market existed for the new fighter as well, as nine European and six other nations were still operating the F-104 in the late 1970s. The CL-1200 concept, on which the Lancer was based, was developed as a private venture by Lockheed and entailed what amounted to a major redesign of the existing F-104 structure. Among the many changes there was a wing structure some 53 percent larger than the Starfighter's, an enlarged vertical tail, high lift devices, additional hard points on the wings, an improved intake design, considerably increased fuel capacity and the installation of a Pratt & Whitney TF-30-P-100 engine. The forward fuselage was to be an F-104S or TF-104G section, depending on whether the aircraft was to be a single or two-seater, mounted on a 30in fuselage extension.

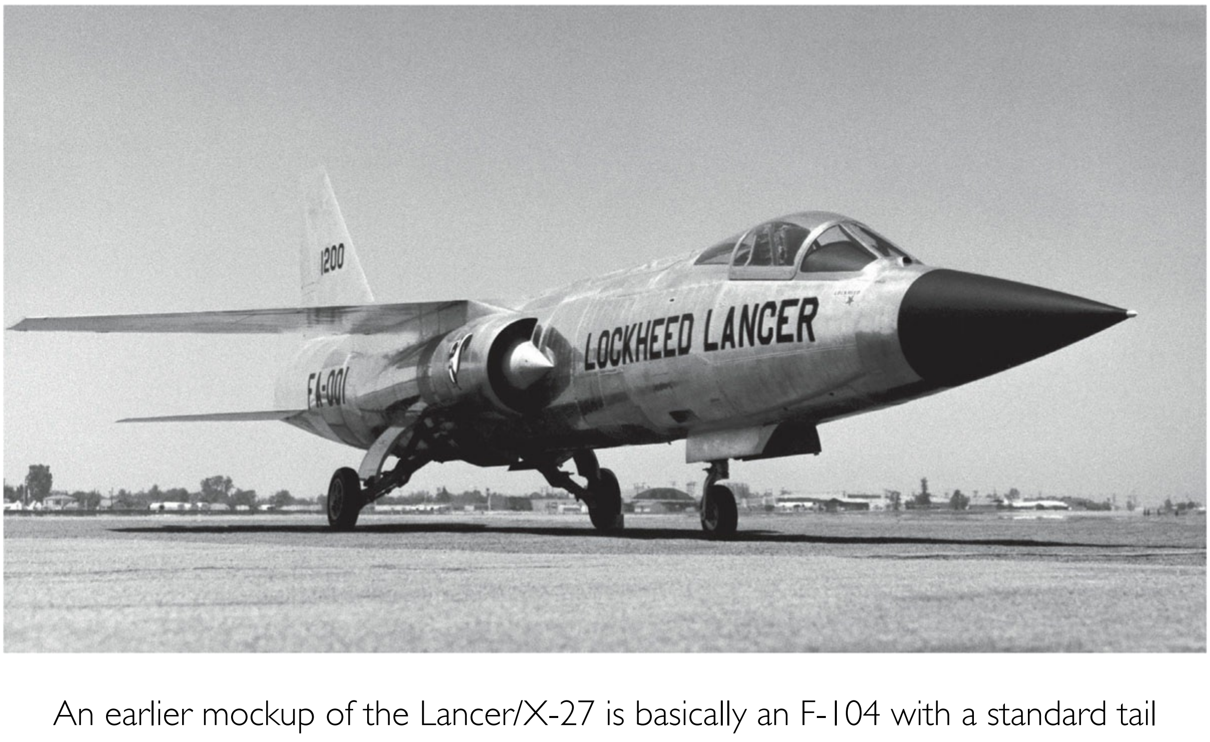
The Lancer project at first appeared to promise an effective lightweight fighter for the 1980s at a cost far below that of any new-design air superiority fighter. Unfortunately, and perhaps incorrectly, certain members of the Air Force felt that the design had the potential to adversely impact development of the then-new F-15 Eagle. As the result, political pressure was applied and the CL-1200 was assigned the experimental designation X-27.

The Lancer offered only limited scope and technological advances when used as a research aircraft; so the Air Force agreed to the request that the type not be built. In the event, no metal was cut and the project died. The Lancer's intended market had been in Europe from the beginning and the Air Force's unwillingness to work with Lockheed on the project had considerable basis in that fact. While the proposed fighter could have, on paper at least, offered a high-performance aircraft at greatly reduced developments costs, it failed to offer the "quantum leap" in technology that would justify extensive American financial involvement. In addition, several new European fighters offered similar performance.



The X-27 was designed to accommodate several different engine options and thus was offered with several different intake designs. The type of inlet in this mockup would have been ideal for the Pratt & Whitney F100-PW family of jet engines. (Author's collection)

A full-scale mockup of the aircraft (which used the forward fuselage of an F-104G and landing gear, and had the wooden fuselage covered by metal skinning) was built and displayed, but no actual flight article was ever constructed and the program quietly faded away.



An earlier mockup of the Lancer/X-27 is basically an F-104 with a standard tail configuration and a wing mounted on top of the fuselage as opposed to mid-fuselage. It would have used the standard F-104 inlet that would be compatible with the General Electric J79-GE family of jet engines. (Author's collection)

YO-3A QUIET STAR

1971

PROGRAM: YO-3A

Name: Quiet Star

Mission: Battlefield observation

Length: 29ft 4in (8.94m)

Wing Span: 57ft (17.37m)

Height: 9ft 3in (2.82m)

Max T.O. Weight: 3,800lb (1,723.7kg)

First Flight: 1971

Last Flight: 1972

Crew: 2

Number Built: 11

Power Plant: 1 x Continental IO-360

Design Speed: Mach 0.11 (80.6mph; 129.7km/h); maximum speed Mach 0.14 (103mph; 165.8km/h)

Service Ceiling: 13,000ft (3,962.4m)

Combat Radius: Endurance: approximately 5 hours

Weapons Load: Night vision systems and laser target designator

Before the advent of unmanned aircraft systems, pilots were the literal eyes and ears in the skies to provide valuable intelligence that would shift the course of many conflicts throughout the world. One of the most successful tools for surveillance and observation was the Lockheed Missiles & Space Company (LMSC) YO-3A aircraft, which was a surveillance aircraft designed to fly silently over the skies of Vietnam, and was one of the first to employ state-of-the-art technologies that paved the way for modern-day surveillance.

The YO-3A was a follow-on to the QT-2 program, since it had been so successful; it aimed to build a more capable silent aircraft that would carry better sensors, have better range and provide better visibility for the crew. The Army was the designated agency to develop the YO-3, with potential operators from all branches of service. The development was initiated in 1968 with the first test flight in December of that year.

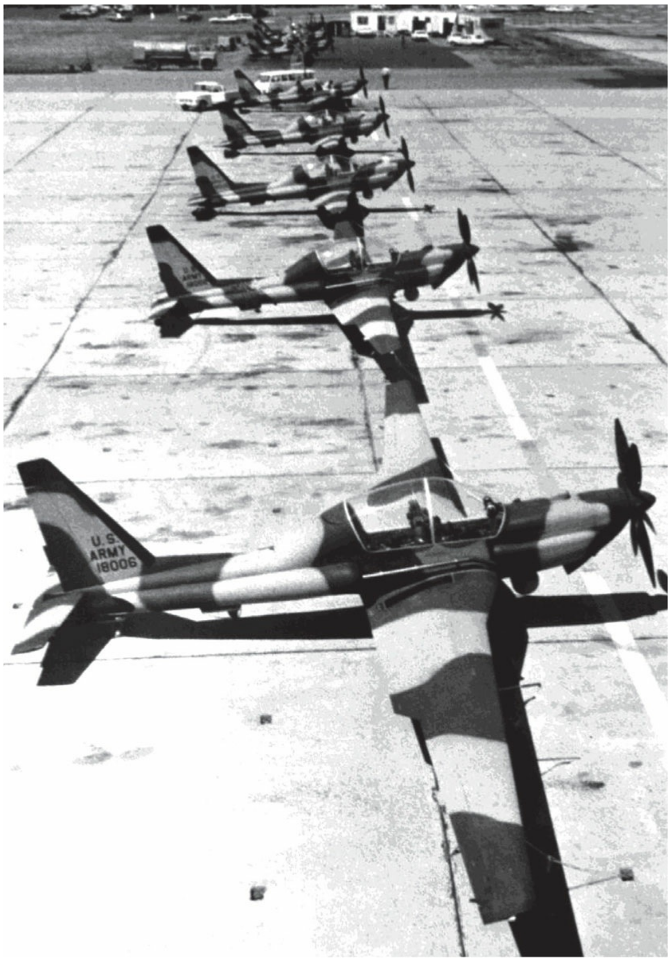
Unlike the QT-2, the YO-3A sported more advanced features, including a front-mounted engine with a 210hp-rated Continental IO-300 reciprocating engine; a night vision aerial periscope with infrared illuminating spotlight; the first-ever airborne laser target illuminator in a production aircraft; and a gimbal-mounted, 6in double viewing prism, the largest ever made at the time, that was capable of viewing a full 360 degrees, as well as 90 degrees up and 105 degrees down.

The first aircraft started out with a six-blade propeller system, but it was soon discovered that in the heat and humidity of Vietnam, the aircraft didn't have very good takeoff performance because the propeller system didn't have enough authority to "bite" the air. So, the designers at Lockheed adopted a three-bladed prop with a very broad blade, and that gave them better takeoff performance. Before the three-bladed propeller, the aircraft had to roll almost a mile to get into the air and the three-bladed prop cut that distance about in half.

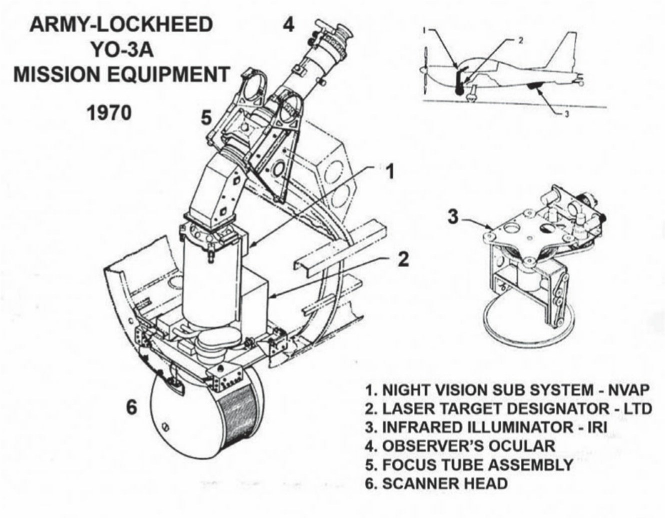
One thing the YO-3A did share with its predecessor was the long wing span, about 57ft, that allowed for better gliding performance when on reconnaissance, but that is where the similarities ceased. The YO-3A also featured internal antennae to reduce noise and drag, as well as a 26ft exhaust, which extended down the starboard side of the fuselage. Each cylinder discharged directly into this exhaust, and it baffled the sound and attenuated it, so at the end of the exhaust, the gas velocity was virtually zero. Although the aircraft's near-silent flight capabilities were impressive, even more impressive was its ability to see at night.

Two systems were developed for this aircraft. The first was the night vision aerial periscope, which used a photo tube of very high sensitivity that could view light across a very broad spectrum, including infrared. That system, which was mounted underneath the aircraft toward the front, was steerable in all directions and also incorporated an infrared spotlight that could be turned on to look at whatever the sight was looking at. Even with the infrared turned off, the night vision aerial periscope (NVAP) was so sensitive that it could detect a candle flame at a distance of over a mile, even on a moonlit night. The viewing prism was also developed specifically for this aircraft and had such a wide viewing spectrum that, as pilots were approaching a target, the observer could keep an eye on a target during approach and as it flew away.

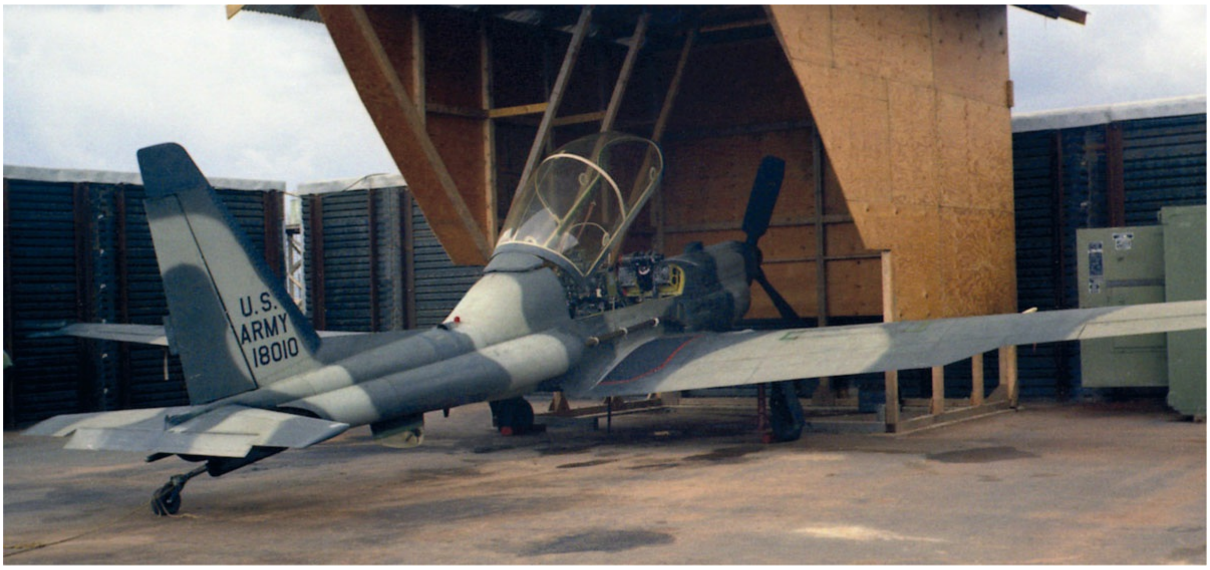
There were 11 YO-3A aircraft deployed to Vietnam in 1971, and with these new technologies, the YO-3A was so successful in its mission that the aircraft were able to fly a total of 1,116 missions and were never engaged by enemy fire. It was just that good at what it did and, as far as we know, the aircraft were never even detected. Although the aircraft was a success, the YO-3A wasn't developed any further for use after Vietnam. But that doesn't mean that its development wasn't instrumental in shaping modern-day aviation. If you look at the features of this aircraft – the very efficient, long, high-aspect ratio wings, its sensor package, the propeller drive – you can see all of this going into today's generation of unmanned aircraft systems (UAS). All of this was essential for the development of the UAS we know today. The technology and experience gained by these aircraft have been used in the development of future surveillance platforms; the groundbreaking optics packages were ahead of their time. Sometimes, when the technology arrives, the mission for which it was intended no longer exists, but all of that information goes into a databank and is rolled forward for use in other programs successfully.


U.S. ARMY 18006

A lineup of eight of the 11 YO-3As built by Lockheed for the US Army in this photo shoot at Moffett NAS, Mountain View, CA. (Author's collection)

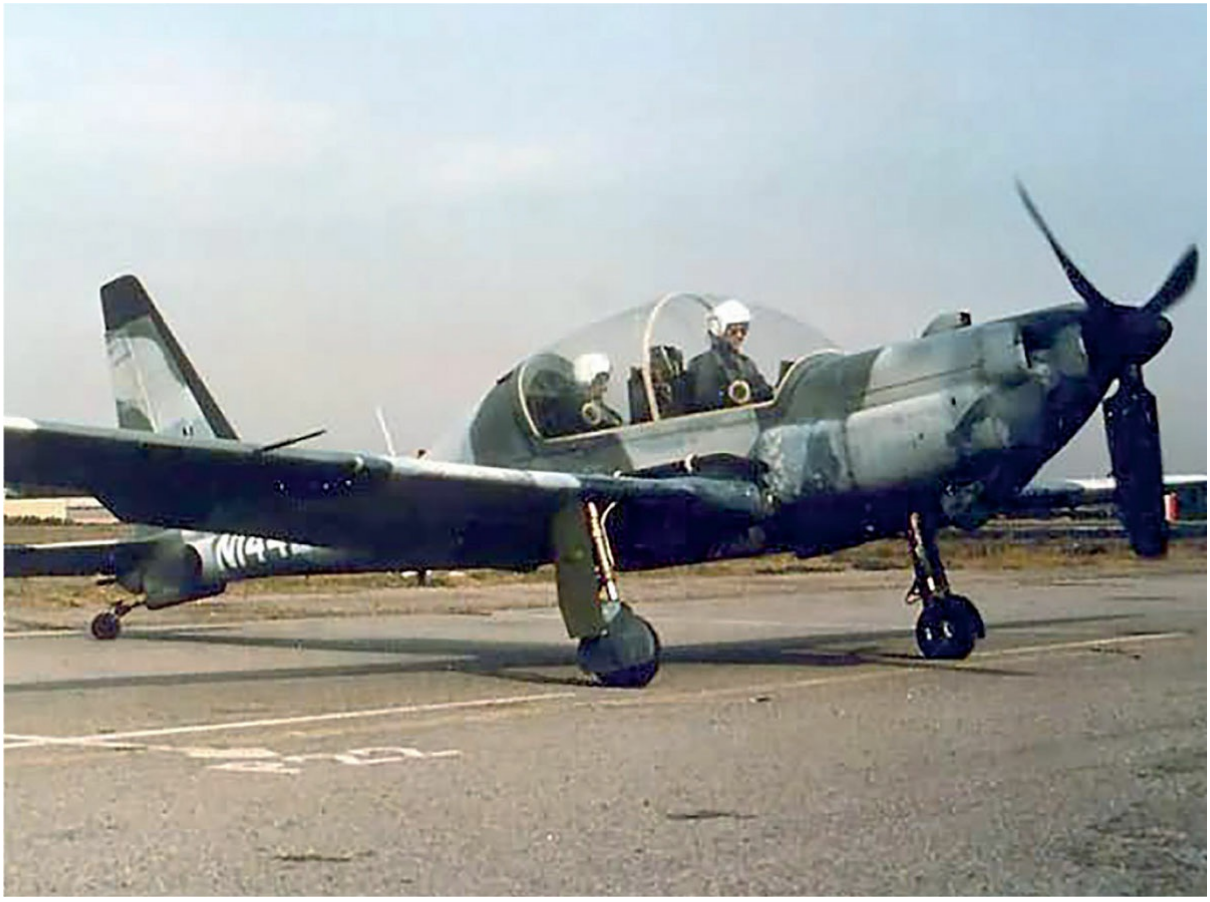

ARMY-LOCKHEED
YO-3A
MISSION EQUIPMENT
1970
1
2
3
4
5
6
1. NIGHT VISION SUB SYSTEM - NVAP
2. LASER TARGET DESIGNATOR - LTD
3. INFRARED ILLUMINATOR - IRI
4. OBSERVER'S OCULAR
5. FOCUS TUBE ASSEMBLY
6. SCANNER HEAD

Technical order illustration for the YO-3A. (Author's collection)

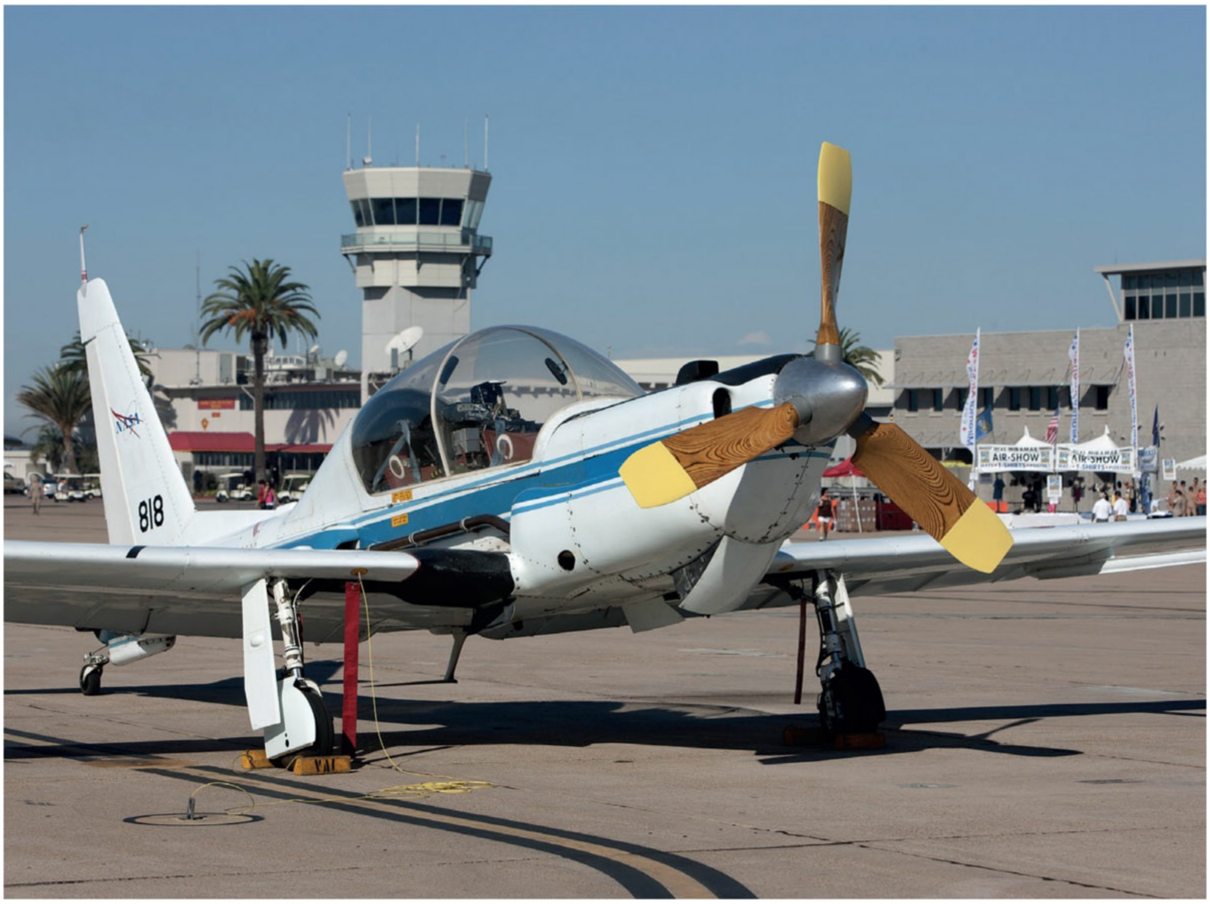


Before serving as a civilian research aircraft the YO-3A, seen here in its original livery taken at Long Thanh-North, Republic of Vietnam, provided the Army with covert, nighttime battlefield surveillance capabilities in Southeast Asia. (Author's collection)

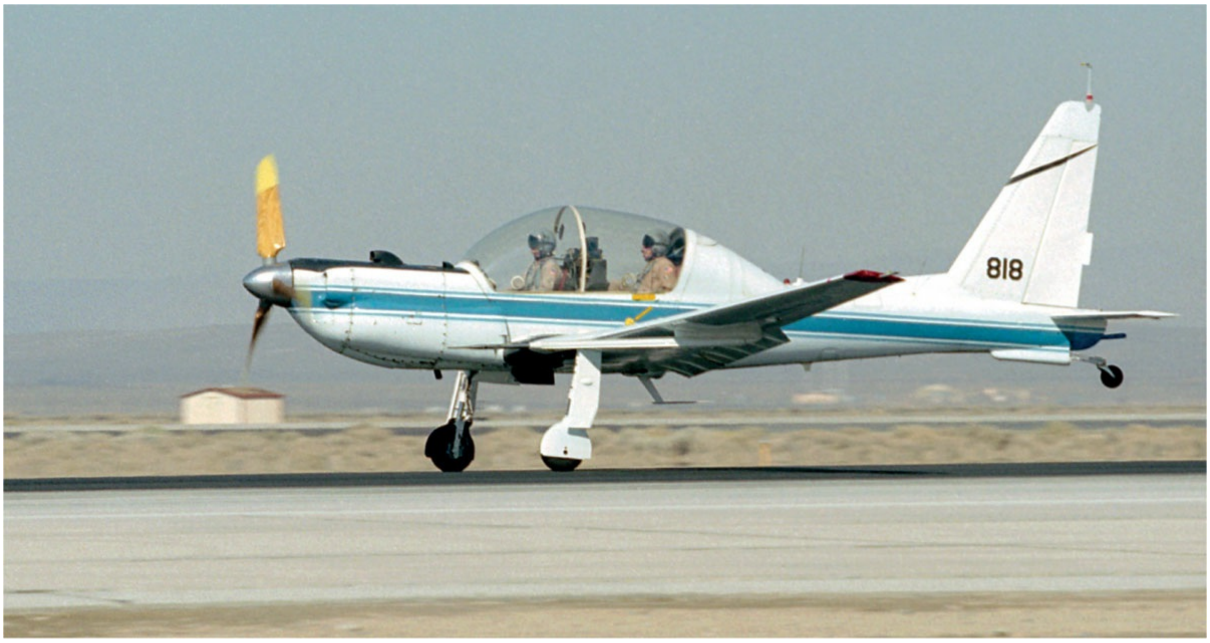
The seventh YO-3A, 69-18007, being serviced at Long Thanh-North, Republic of Vietnam, in the spring of 1971. (Author's collection)



Built for the US Army in 1969, this is one of two YO-3A's that went to the Louisiana Department of Wildlife after they returned from a three-year tour in Vietnam. Registered N 14425 and N 14426, they were former Army serial numbers 69-18006 and 69-18007. Later they were registered to the FBI. (Author's collection)



This particular YO-3A flew combat missions in Vietnam and was later sold to an airframe and power plant mechanics school. (NASA)

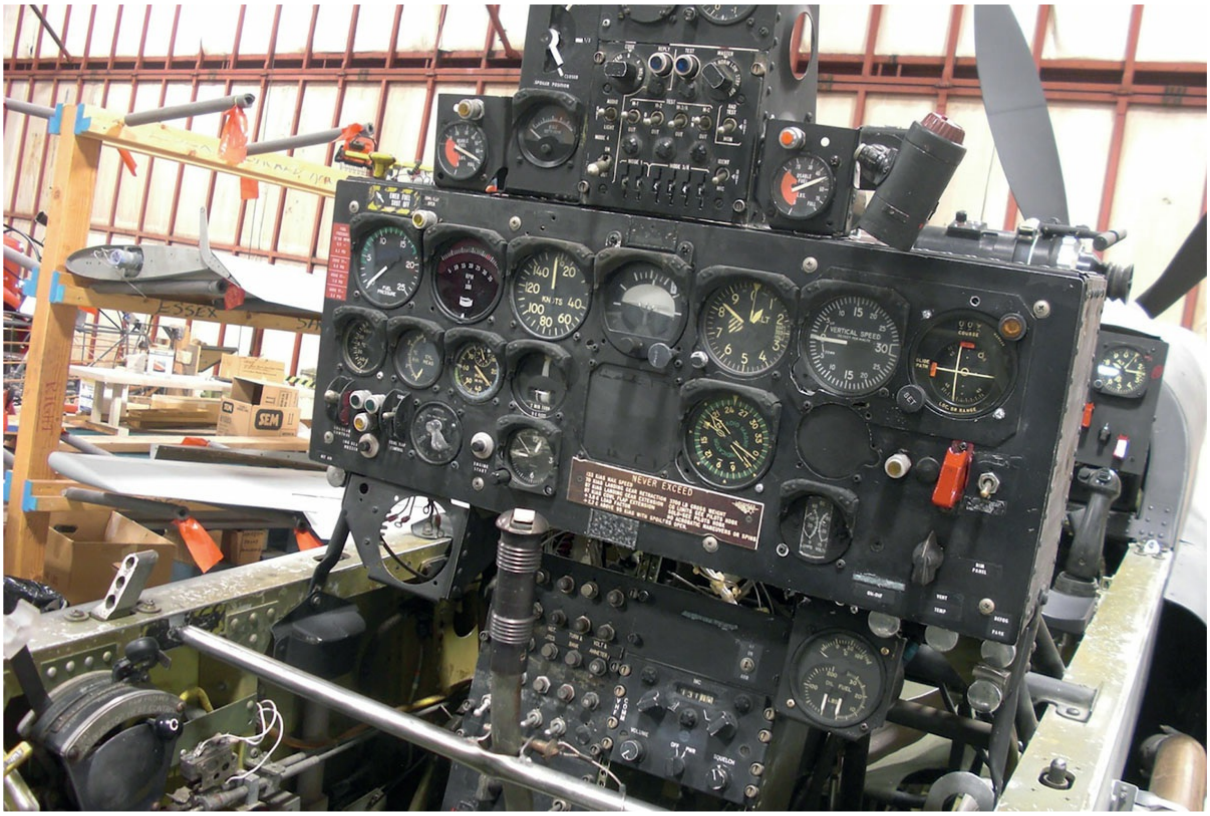


The YO-3A was easily recognizable by its narrow wings, distinctive bubble canopy and wide-bladed wooden propeller. The pilot sat in the back while the observer occupied the front seat. (NASA)

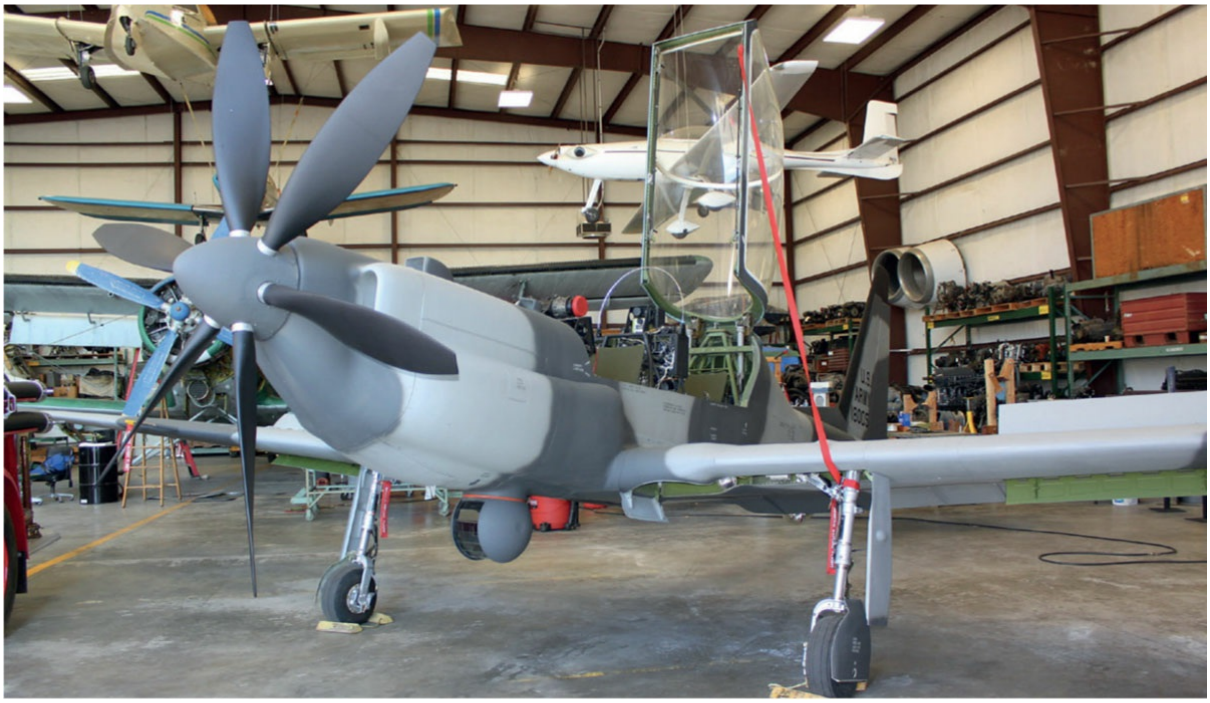
Lockheed YO-3A Quiet Star, serial number 69-18006, taken at the Pima Air and Space Museum in August 1991. (Author's collection)

The Museum of Flight's YO-3A at the museum's restoration center located at Paine Field, Everett. (James C. Goodall)

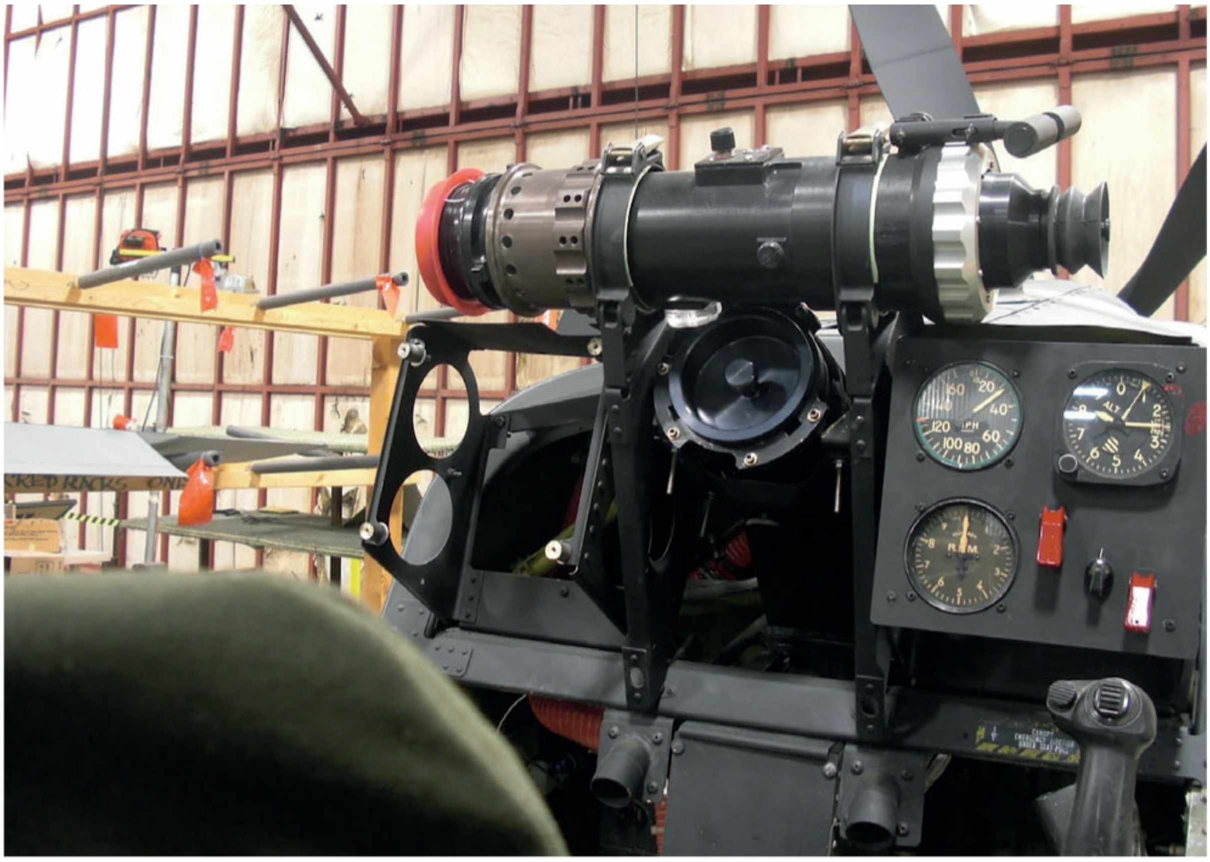
A look-down view of the partially restored YO-3A at the Museum of Flight's restoration center at Paine Field, Everett, WA. (James C. Goodall)


KNOTS
VERTICAL SPEED
NEVER EXCEED
ESSEX
SEM

The rear cockpit of the Lockheed YO-3A is dedicated to the pilot as the observer needs to have an unobstructed view out of the very large bubble canopy. (James C. Goodall)



A nose-on view of the finished restoration of the YO-3A at the Museum of Flight's restoration center at Paine Field, Everett. (James C. Goodall)



The observer's location is in the forward cockpit, much as in today's attack helicopters. The nocturnal vision package aboard the YO-3A included an articulated and stabilized night vision aerial periscope (NVAP) and infrared illuminator (IRI) able to sweep 360 degrees in horizontal from nadir to +15 degrees in vertical from the airframe. (James C. Goodall)

X-24C L-301

1977

PROGRAM: L-301

Name: X-24C (designation never officially issued)

Mission: NASA & USAF flight-test

Length: 74ft 10in (22.81m)

Wing Span: 24ft (7.32m)

Height: 20ft 7in (6.27m)

Max T.O. Weight: 70,000lb (31,751kg)

First Flight: X-24C concept study July 1974

Last Flight: Program canceled September 1977

Crew: 1

Number Built: N/A

Power Plant: Thiokol LR-105 rocket engine plus 12 LR-101 sustainer engines

Design Speed: Mach 8 (6,140mph; 9,881.4km/h)

Service Ceiling: 100,000ft (30,480m)

Combat Radius: N/A

Weapons Load: N/A

As the North American Aviation X-15 program wound down in the mid-1960s, NASA and the USAF considered follow-on hypersonic test aircraft. The USAF had significant classified work underway, while NASA Langley undertook two study programs: HYFAC (Hypersonic Research Facility) for a Mach 12 aircraft, and HSRA (High Speed Research Aircraft) for a Mach 8 aircraft. The Air Force revealed that it had intentions to build a Mach 3–5 test vehicle, and an incremental growth vehicle which would gradually be taken from Mach 4.5 to Mach 9. By July 1974 NASA and the Air Force selected the FDL-8 lifting body configuration. Two versions were proposed: one with cheek air intakes and air-breathing engines, and one with the XLR-99 rocket engine of the X-15. By September 1977 (officially) budget overruns were apparent and NASA agreed to cancel further X-24C work. But given the stories of similar USAF test aircraft in the 1980s, perhaps the project merely went deep black.

The Lockheed L-301, also called the X-24C, though this designation was never officially assigned, was an experimental hypersonic aircraft project. NASA and the Air Force organization, the National Hypersonic Flight Research Facility, with the Lockheed Skunk Works as the prime contractor, developed it. Beginning in January 1977, the program was tentatively scheduled to operate two vehicles for eight years and to conduct 100 flights per vehicle.

Originally intended to carry the same XLR-99 engine used by the X-15, the primary engine was changed to the LR-105, which was the sustainer engine used on the Atlas launcher. This rocket engine, burning RP-1 and liquid oxygen (LOX), was intended to accelerate the X-24C to hypersonic speeds in order to ignite the hydrogen-fueled, air-breathing ram/scramjet (supersonic-combustion ramjet) mounted in the belly of the airframe with which it would attain cruise speeds of at least Mach 6 and peak velocities of Mach 8+ at altitudes of 90,000ft or more. As such, this vehicle was plainly not intended to reach orbit.

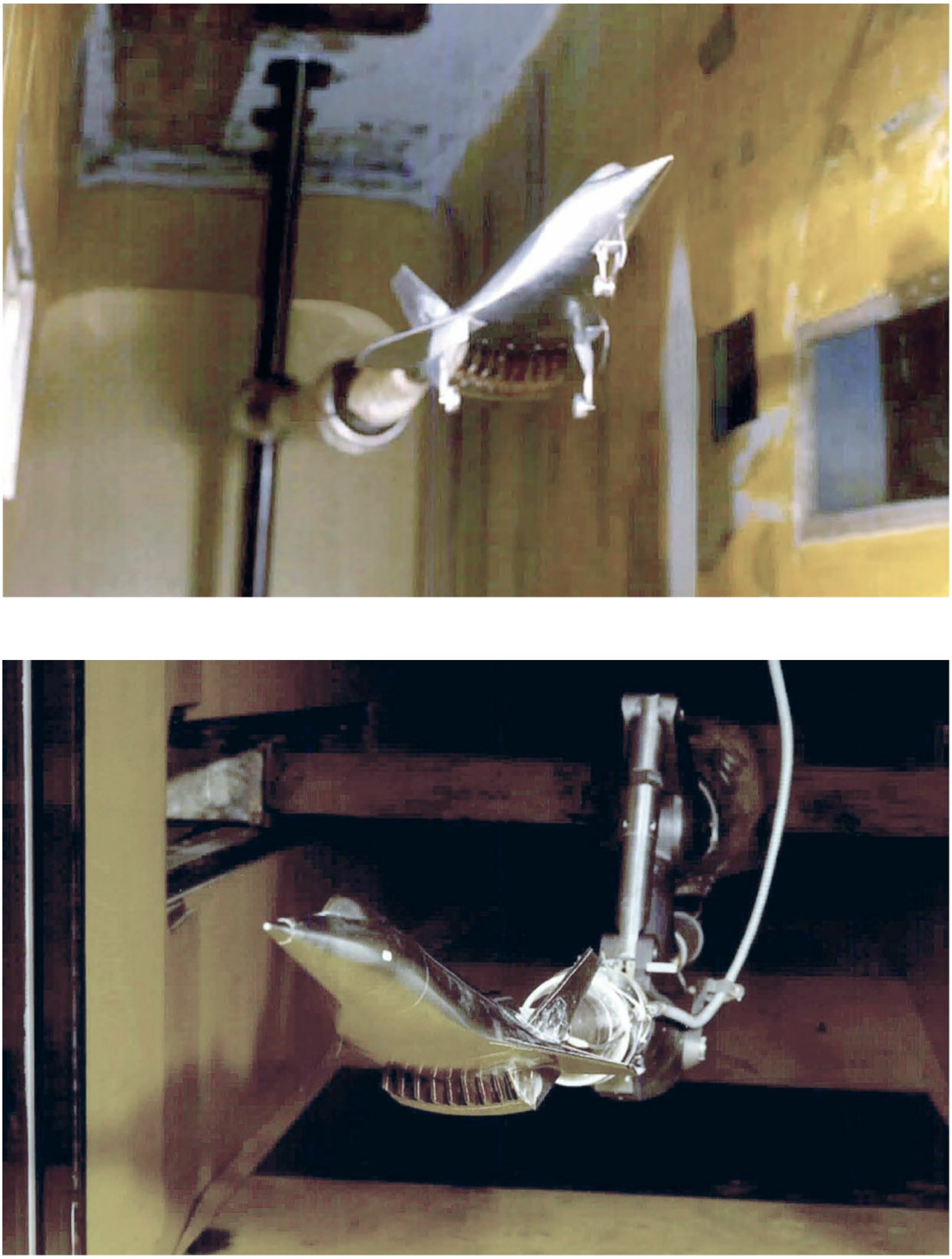
Each mission was to start with a subsonic launch from the B-52 launch vehicle, at 45,000ft above Mean Sea Level (MSL), where its boost rocket engine was ignited to accelerate. At this point, the X-24C vehicle was heavy with large loads applied to the structure due to the positive 2.5g limit maneuver and rocket axial thrust. Vehicle structure would have remained relatively cool during this initial maneuver. At the end of the acceleration phase a 0g pushover would have been initiated to align the vehicle for the desired cruise condition. At the start of the cruise phase, the takeoff mass had been reduced approximately 50 percent. The structure was increasing in temperature towards a peak shortly after the end of the cruise segment. To stay within the test range constraint, the X-24C would perform a high drag 3g pullup combined with a banking maneuver at the time of cruise power burnout. During these maneuvers, airframe temperatures, combined with flight loads during deceleration, would cause the structure to cool.

The mission for the cruise on sustainer rockets exactly followed the flight profile noted above for scramjet cruise. The dash to Mach mission followed the same profile as for the scramjet mission, except the acceleration phase was extended to Mach 7.8. Level flight was obtained at the end of the acceleration phase followed by the deceleration maneuver identical to the one used in the scramjet mission. Heating peaks occurred shortly after the start of deceleration, as in the scramjet mission, but were not as high as in the Mach 6.6 mission due to the shorter mission elapsed time involved. Consideration of this mission, however, was made due to the difference in the vehicle shell temperature gradients in the non-scramjet configuration.

They were originally scheduled to fly 200 flights over eight years, reaching a maximum speed of Mach 8 and being able to cruise at over Mach 6 for 40 seconds.

NASA
U.S. AIR FORCE
X-24C
LOCKHEED
CALIFORNIA COMPANY
X-24C

A desk model of the X-24C made for Lockheed. (Author's collection)



The X-24C went through a series of major design changes and design improvements and associated performance upgrades. The X-24C-L301, a true Skunk Works design, could be powered by either scramjets or rocket power. (Author's collection)

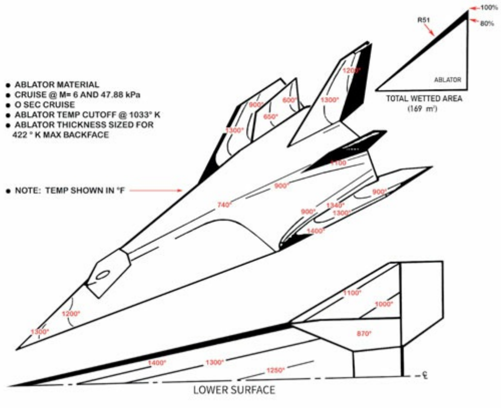
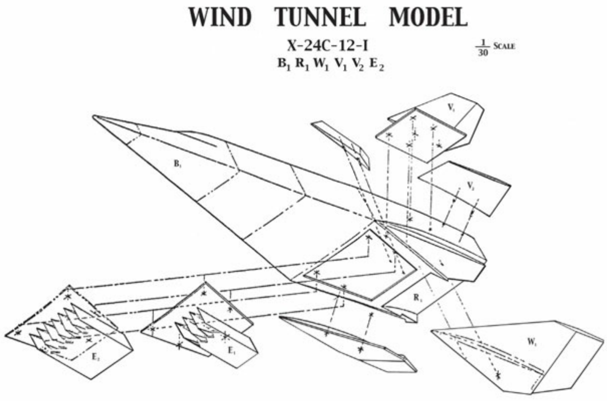

R51
100%
80%
ABLATOR
TOTAL WETTED AREA
(169 m²)
• ABLATOR MATERIAL
• CRUISE @ M= 6 AND 47.88 kPa
• O SEC CRUISE
• ABLATOR TEMP CUTOFF @ 1033° K
• ABLATOR THICKNESS SIZED FOR 422 ° K MAX BACKFACE
• NOTE: TEMP SHOWN IN °F
1200°
900°
600°
650°
1300°
1300°
1100
900°
740°
900°
1340°
1300°
900°
1400°
1200°
1300°
1100°
1000°
870°
1400°
1300°
1250°
LOWER SURFACE

Figure 50 - Ablator Surface Area - Mach 6 / 1033° K


WIND TUNNEL MODEL
X-24C-12-I
1/30 SCALE
B₁ R₁ W₁ V₁ V₂ E₂
B₁
V₁
V₂
R₁
W₁
E₁
E₂

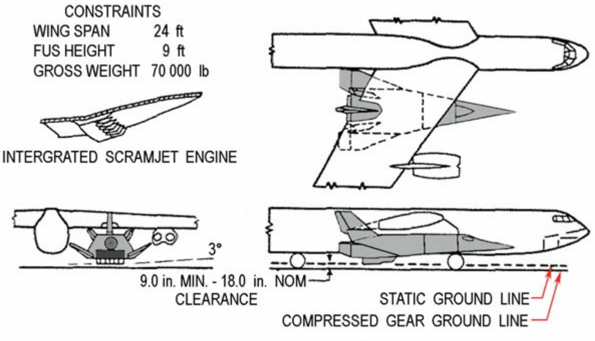

CONSTRAINTS
WING SPAN 24 ft
FUS HEIGHT 9 ft
GROSS WEIGHT 70 000 lb
INTERGRATED SCRAMJET ENGINE
3°
9.0 in. MIN. - 18.0 in. NOM
CLEARANCE
STATIC GROUND LINE
COMPRESSED GEAR GROUND LINE

Fig. 1 B-52 launch aircraft contraints.

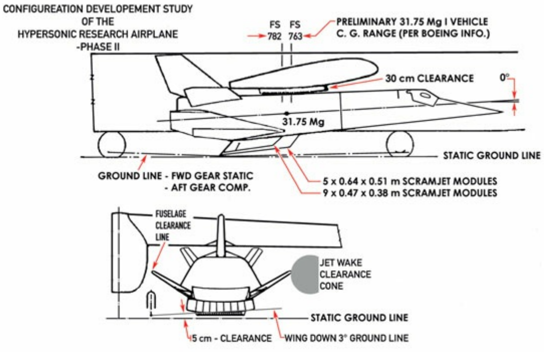
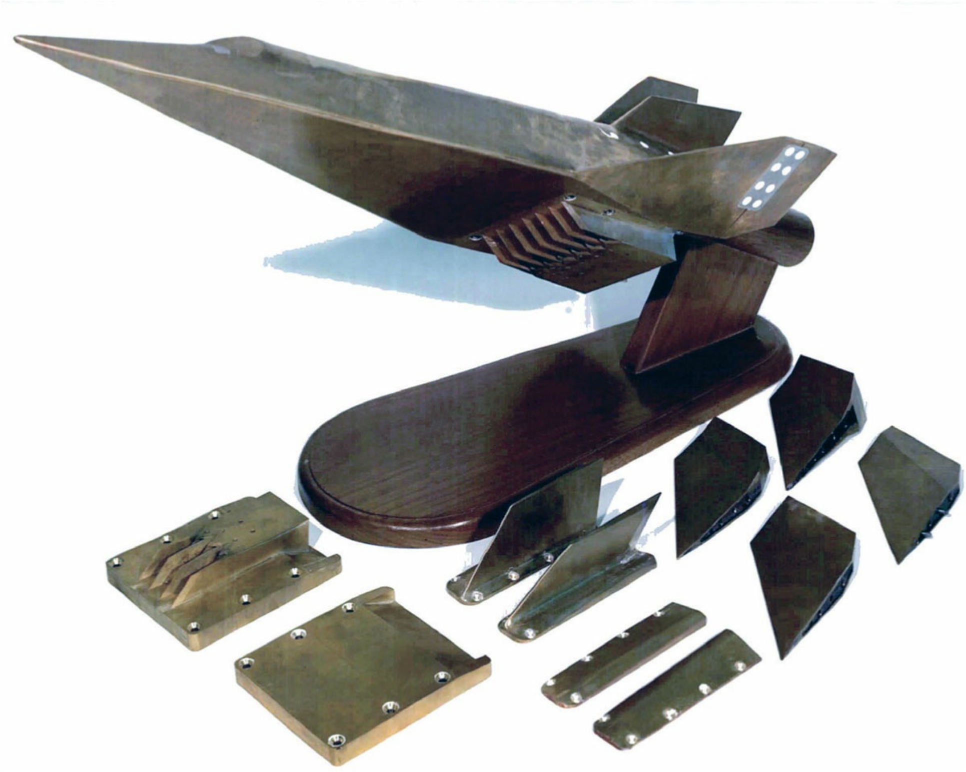

CONFIGUREATION DEVELOPEMENT STUDY
OF THE
HYPERSONIC RESEARCH AIRPLANE
-PHASE II
FS 782
FS 763
PRELIMINARY 31.75 Mg I VEHICLE
C. G. RANGE (PER BOEING INFO.)
30 cm CLEARANCE
0°
31.75 Mg
STATIC GROUND LINE
GROUND LINE - FWD GEAR STATIC
- AFT GEAR COMP.
5 x 0.64 x 0.51 m SCRAMJET MODULES
9 x 0.47 x 0.38 m SCRAMJET MODULES
FUSELAGE
CLEARANCE
LINE
JET WAKE
CLEARANCE
CONE
STATIC GROUND LINE
5 cm - CLEARANCE
WING DOWN 3° GROUND LINE

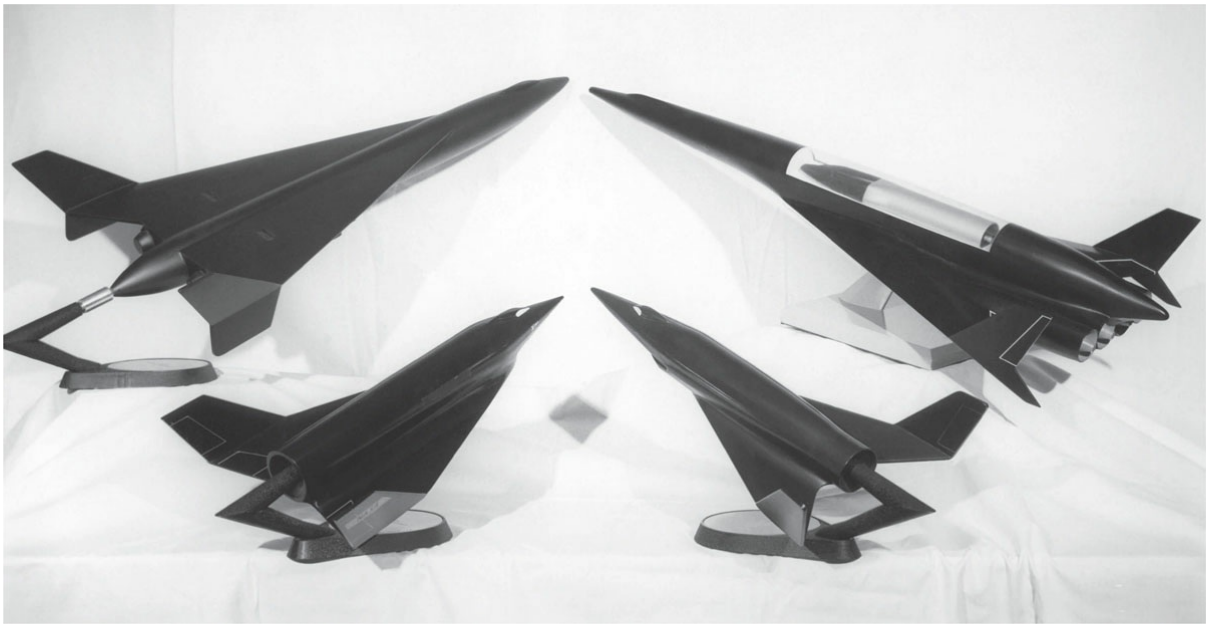
Figure 6 - X-24C/B-52 Interface

Technical illustrations redrawn by the author. (Author’s collection)

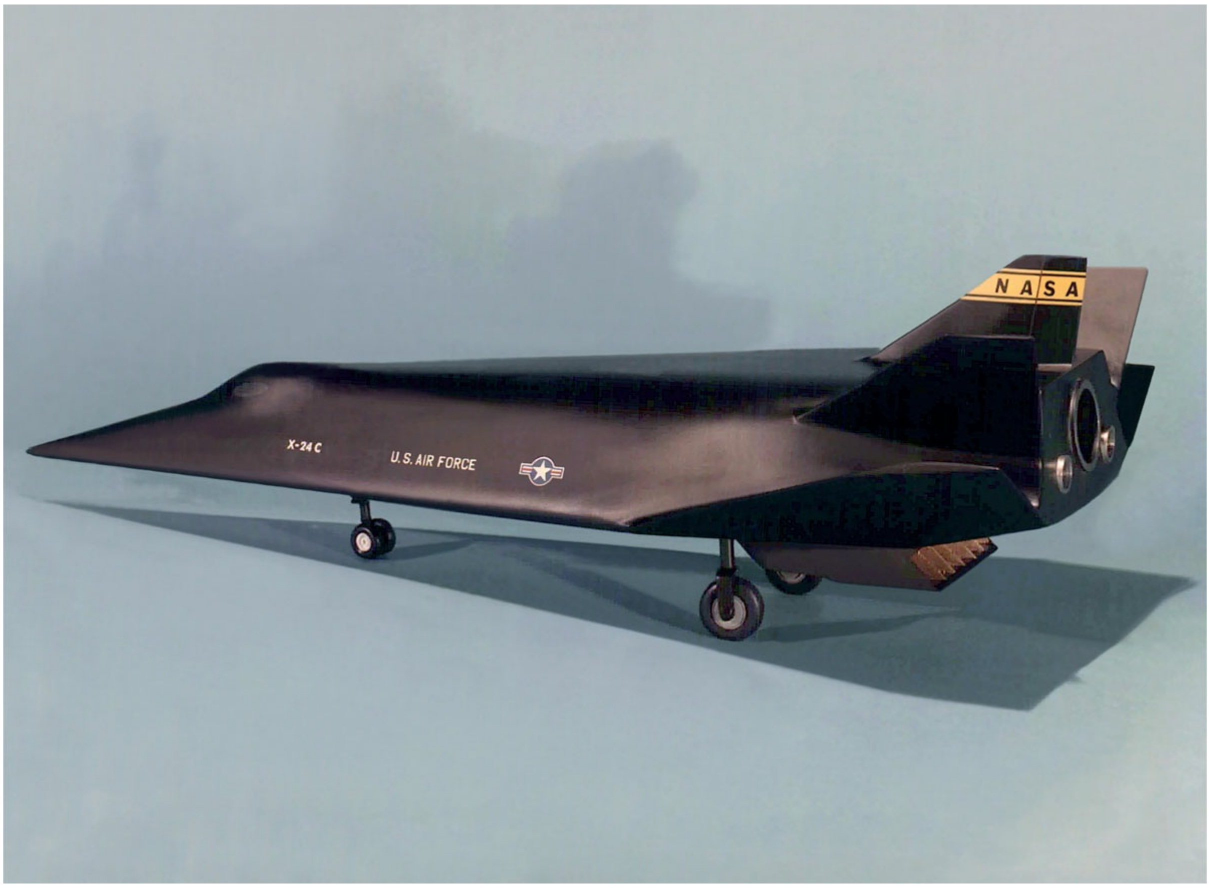
An X-24C model undergoes basic aerodynamic testing and evaluation in Arnold Engineering Development Center's 16ft transonic propulsion wind tunnel in 1974. (AEDC)



Small wind tunnel model of the X-24C with various different pieces and parts that could be interchanged with minimal downtime. (Author's collection)



The design innovation in the development of the X-24C family is evident in the various configurations in the accompaning photo. Much like the wind tunnel models, the proposed variations to the X-24C allowed for the complete change in the exterior mold line of the different configurations. (Author's collection)


NASA
X-24C
U.S. AIR FORCE

The X-24C desktop model with landing gear. (Author's collection)

XST HAVE BLUE

1977

PROGRAM: XST (EXPERIMENTAL SURVIVABLE TESTBED)

Name: Have Blue

Mission: Technology demonstrator

Length: 47ft 3in (14.40m)

Wing Span: 22ft 6in (6.86m)

Height: 7ft 6in (2.29m)

Max T.O. Weight: 12,500lb (5,670kg)

First Flight: 1 December 1977 (Have Blue 1)

Last Flight: 11 July 1979 (Have Blue 2)

Crew: 1

Number Built: 2

Power Plant: 2 x General Electric J85-GE-4A

Design Speed: Mach 0.79 (600mph; 966km/h)

Service Ceiling: 18,000ft (5,486.4m)

Combat Radius: N/A

Weapons Load: N/A

Despite the F-117's public image as the most modern of warplanes, the radar-evading aircraft had its technical origins late in the administration of President Dwight D. Eisenhower. Hula-Hoops were in vogue when Lockheed's Kelly Johnson and Ben Rich turned their attention to improving on the U-2 spyplane then flying reconnaissance patrols over the Soviet Union.

"Much to our amazement," Mr Rich recently recalled, "the Russians tracked us all the way. They couldn't do much about it, but they tracked us." Then the USSR shocked the world in May 1960, when it shot down a U-2 and captured its pilot, Francis Gary Powers.

The CIA asked Lockheed to investigate ways to reduce the radar cross section (RCS) of advanced aircraft. The team achieved early success in its work on the A-12 and, later, the SR-71 Blackbird, reducing the RCS of the planes by two orders of magnitude. Two years later, the D-21 unmanned drone achieved a reduction of another order of magnitude. The SR-71 was a breakthrough, according to Paul Martin, the program manager at Lockheed Advanced Development Company. It was in the SR-71 program, he said, that Lockheed "first developed aircraft shaping methods, radar absorbing structural edges, radar absorbing coatings, and other design features that greatly reduced the SR-71's radar signature."

In 1975, both Lockheed and Northrop were awarded Phase I contracts for four-month projects that would conclude with model tests and selection of one firm for a Phase 2 award. Both presented concepts that were predicted to meet or exceed the signature goals. Early in Phase 1, the program was classified "Top Secret." Lockheed and Northrop were to construct one-third and full-scale pole models, which were then tested on a radar range to see which company best met the criteria of the Defense Advanced Research Projects Agency (DARPA) for a high-stealth aircraft. Lockheed Skunk Works engineers determined that an airplane with faceted surfaces could have a remarkably low radar signature because the surfaces would radiate 99.9 percent of the radar energy away from the receiver.

They built a model called "the Hopeless Diamond" because it looked like a squat diamond and looked too hopeless ever to fly. This work marked a substantial change from the past because, for the first time, designers realized that it might be possible to make an aircraft that was virtually invisible to radar.

Following the results of the "Pole Off," Lockheed won the sole Phase 2 award and were awarded the contract to build two sub-scale demonstrator aircraft (about 50 percent of the size of an operational airplane). Lead responsibility for the program was transitioned from DARPA to the Air Force Special Projects Office, and the program became known as Have Blue.

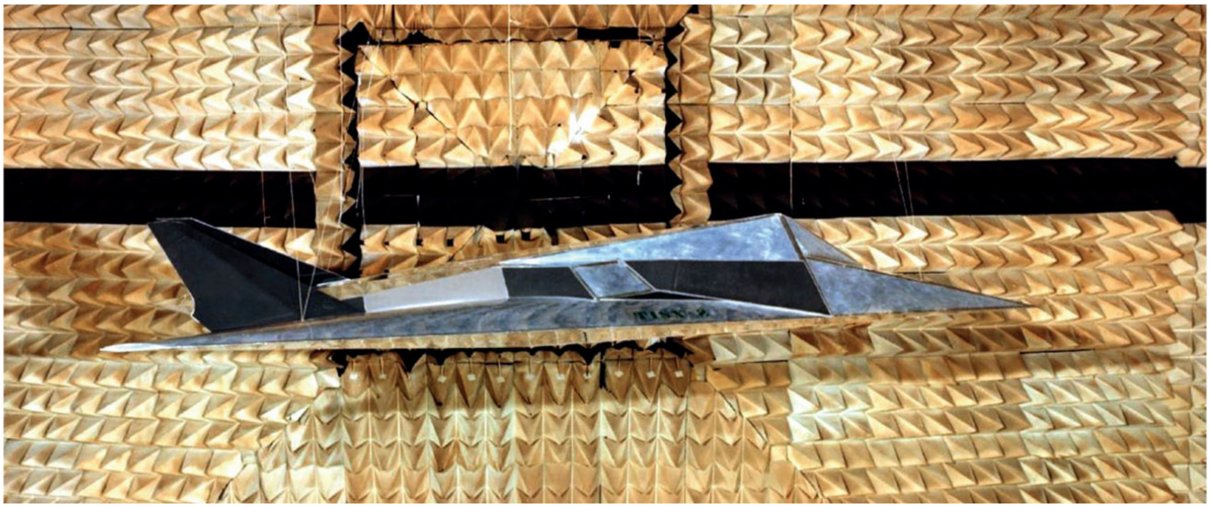
The Phase 2 program Have Blue began in 1976. Have Blue was a proof-of-concept aircraft designed to test out Lockheed's concepts for very low-observable capabilities while meeting a set of realistic operational requirements. Phase 2 was conducted as a classified Special Access program, managed by a special office within Air Force Systems Command and utilizing special oversight procedures for congressional review. Nonetheless, Lockheed's Skunk Works managed the program in an environment open to experimentation and flexible problem solving, with a high degree of communication among scientists, developers, managers and users. The Office of the Secretary of Defense leadership kept the program focused and moving forward – Phase 2 was deliberately limited to demonstrating that the RCS objectives could be achieved – in the face of many fundamental uncertainties.

Under Have Blue, Lockheed built two manned technology demonstrators to validate Lockheed's pole model results. They were kept as small and simple as possible to minimize cost. There was no mission equipment, the cockpit was unpressurized, and the aircraft had no air-to-air refueling capability. Only the second aircraft had radar absorbing material (RAM) coatings. Have Blue was approximately one-quarter scale in weight to the eventual F-117A.

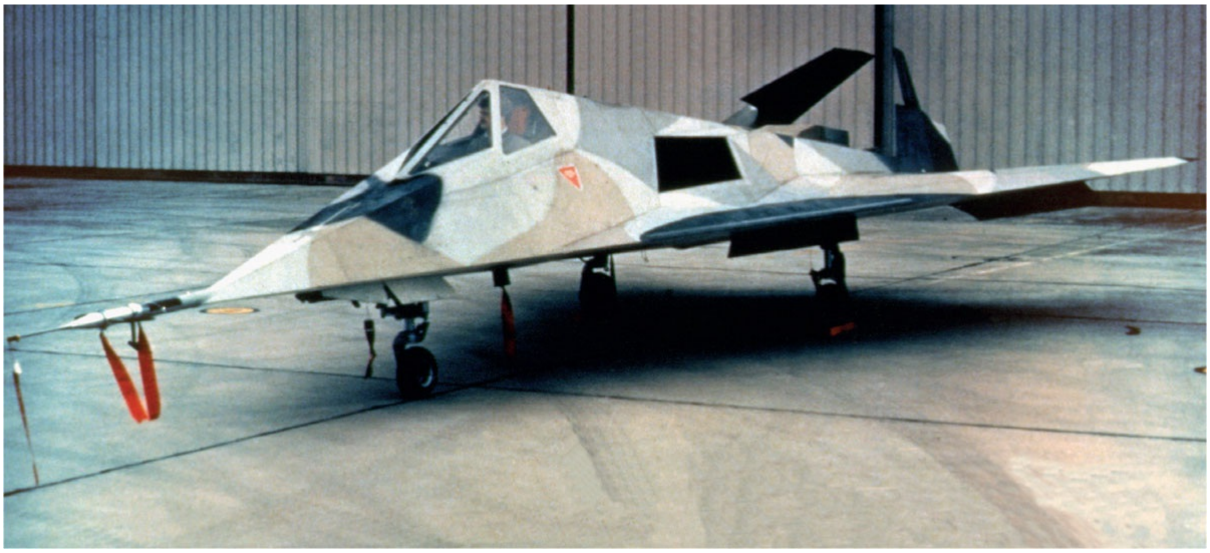
The cross section of the vertical stabilizers was generally of diamond shape. The inward tilt of the stabilizers was considered to minimize radar cross section, since this configuration tends to hide, or mask, other elements. The angles of the tail surfaces, with an inward tilt therebetween, enhanced the ability of the vehicle to display a minimum radar cross section while retaining the ability to function with reasonable aerodynamic efficiency.

Even though these test vehicles made use of conventional off-the-shelf components and subsystems, they were truly revolutionary. Their shaping and materials were so important that their impact on aircraft survivability changed the way the USAF fights. Technologies nurtured by DARPA included RCS reduction, RAM development, infrared shielding, reduced visual signatures, low-probability-of-intercept radar, inlet shielding, exhaust cooling and shaping, and other signature reduction disciplines.

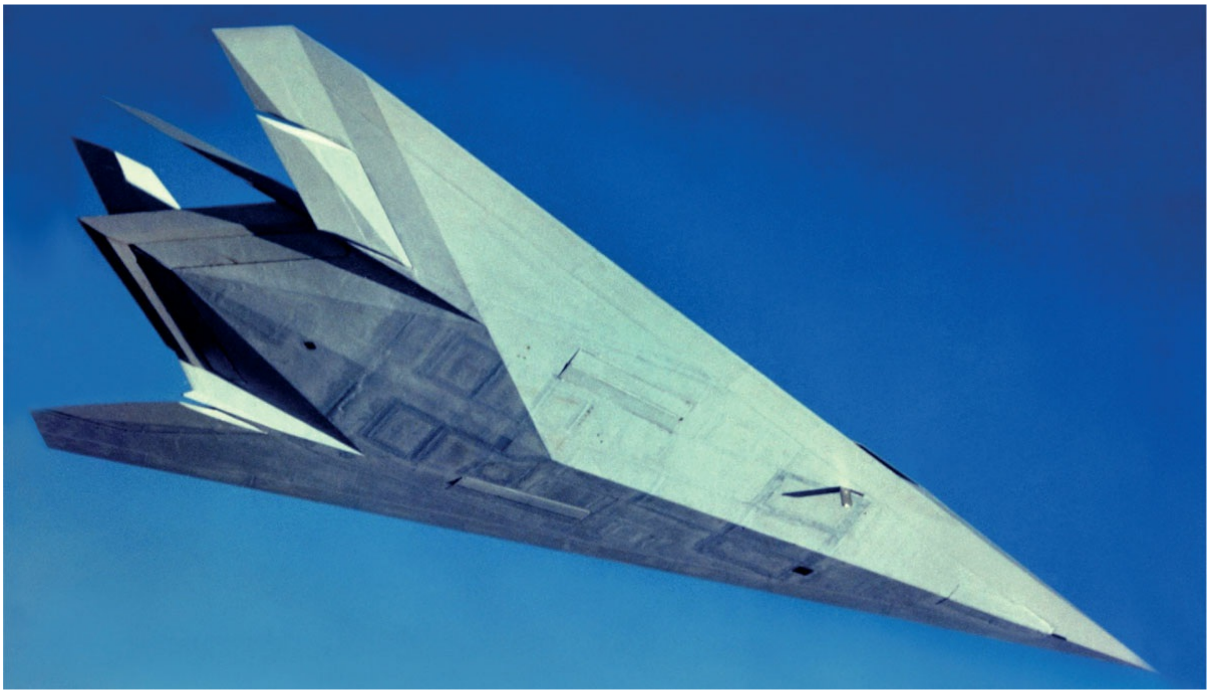
Several Have Blue RCS pole models were built, most using the same aluminum substructure covered with radar absorbing materials (RAM). (Lockheed Martin)



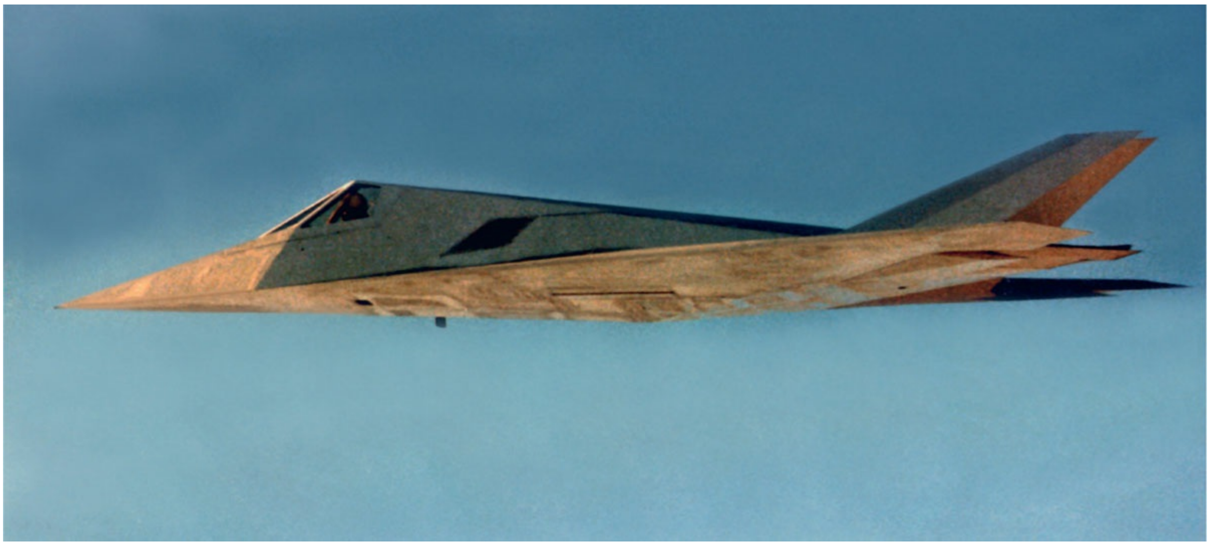
A small-scale Have Blue RCS model in Lockheed's former Rye Canyon anechoic chamber. (Lockheed Martin)



The first Have Blue was equipped with a conventional nose boom for airspeed, altitude, angle-of-attack and sideslip sensing. (Lockheed Martin)

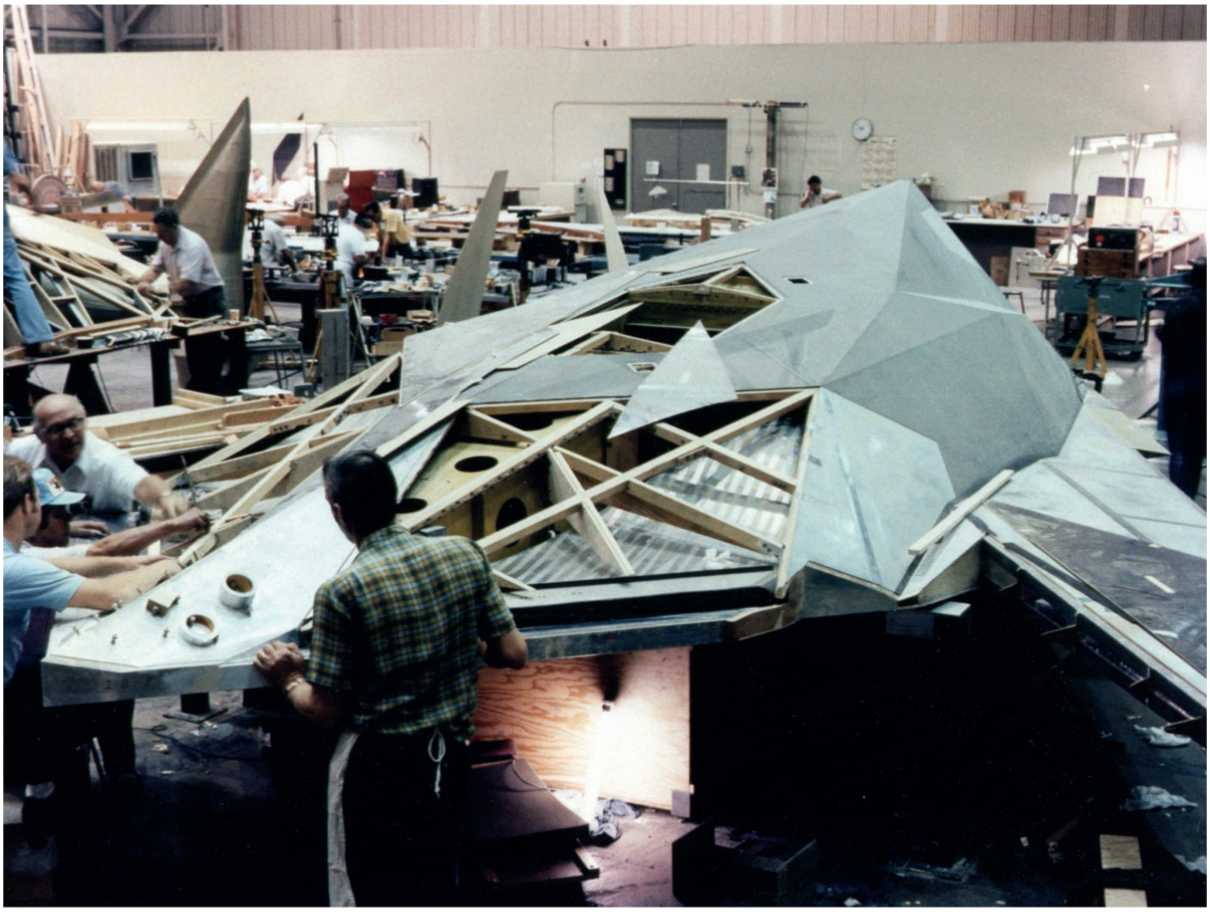


The second Have Blue prototype undergoing flight-test out of Area 51. The second Have Blue was flown without the flight-test boom used on the first one, and without the drag chute housing that was located between the twin vertical tails. (Lockheed Martin)

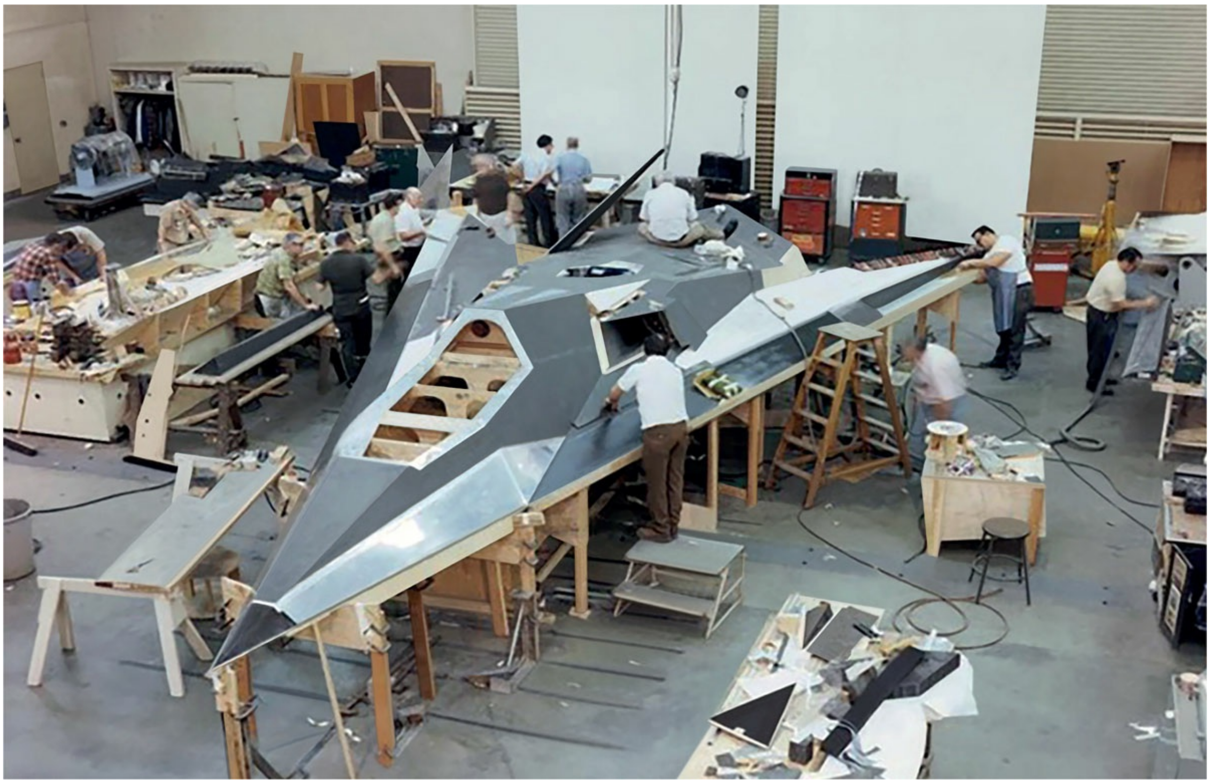


The second Have Blue was flown 52 times. (Lockheed Martin)

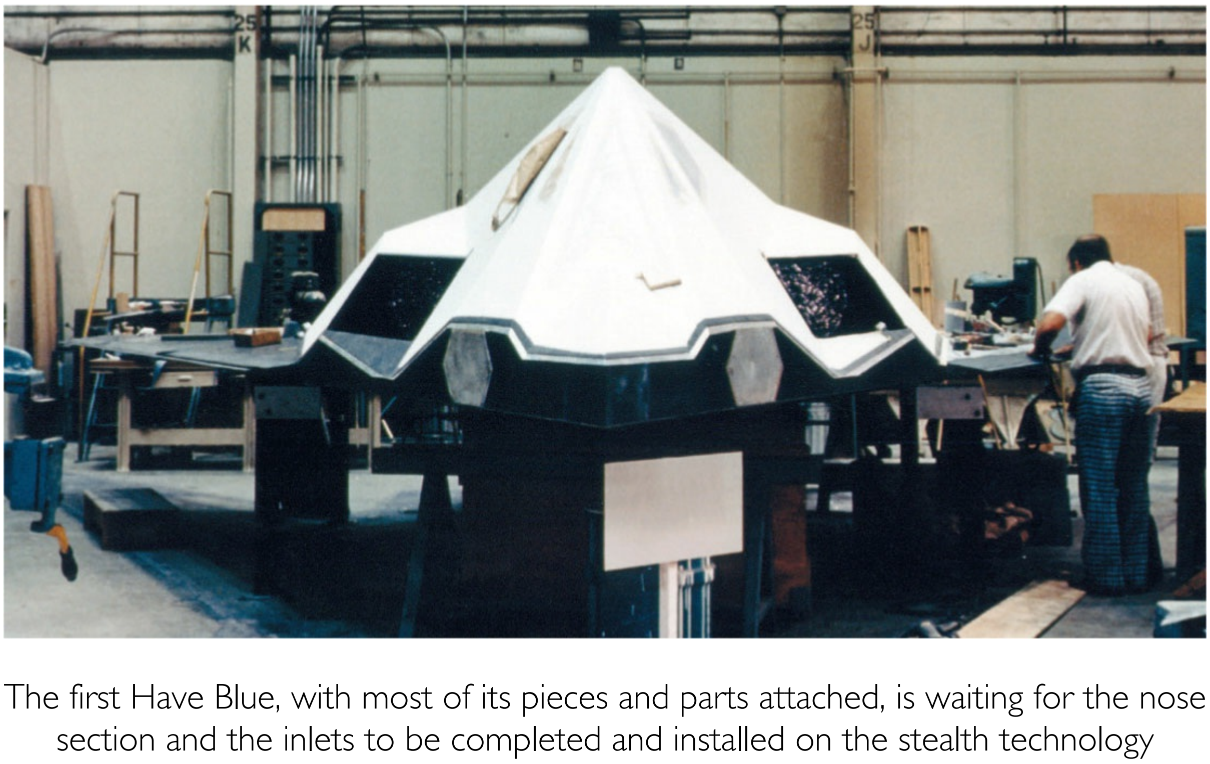
All ground testing on the initial Have Blue aircraft was conducted at Lockheed's Burbank production facility. Engine runs were made at night after the Hollywood Burbank Airport had closed for the night. Following engine runs, the Have Blues were disassembled and flown to Area 51 via Air Force C-5As delivered there on 16 November 1977 and reassembled for flight-testing. (Lockheed Martin)



Once a majority of the testing was behind them, Lockheed's talented shop people started in earnest in building a full-scale wooden mockup of the F-117 in late 1979. The faceted surface detail mimicked the technology generated from the Have Blue program. (Lockheed Martin)



A view of the nose of the Have Blue RCS pole model during build up at the Lockheed Martin main production facility in Burbank, CA, in early 1977. Most of the major parts are in place and the final pieces built are ready to be attached. (Lockheed Martin)



The first Have Blue, with most of its pieces and parts attached, is waiting for the nose section and the inlets to be completed and installed on the stealth technology demonstrator. (Lockheed Martin)

SENIOR PEG

1978

PROGRAM: SENIOR PEG

Name: Advanced Technology Demonstrator

Mission: Advance technology bomber

Length: 72ft (21.9m) estimated

Wing span: 165ft (50.3m) estimated

Height: 17ft (5.2m) estimated

Max T.O. Weight: 336,500lb (152,634kg) estimated

Ferry Range: Intercontinental with air-to-air refueling

First Flight: Request for proposal (RFP) only

Last Flight: RFP only

Crew: 2 with optional unmanned capabilities

Number Built: RFP only

Power Plant: 4 x General Electric F118-GE-100 engines

Design Speed: Mach 0.7 (519mph; 835km/h)

Service Ceiling: 55,000ft (16,764m)

Combat Radius: Intercontinental with air-to-air refueling

Weapons Load: 40,000lb (18,145kg) conventional or nuclear weapons

Stealth technology slithered from near-obscurity to the dark shadows of America's top-secret aircraft design houses in the mid-1970s. A small but growing group within the Pentagon's Defense Advanced Research Projects Agency (DARPA) wanted to explore the possibility of building a tactical aircraft that appeared as close to invisible as possible on radar.

This initiative gelled into the Experimental Survivable Testbed (XST) competition, which would lay down the stealth gauntlet to America's top military aircraft designers. The goal was simple: to design a tactical aircraft concept that could all but disappear on radar, a tall order during a time when even predicting the radar reflectivity of basic shapes was challenging. In the end, Lockheed's Skunk Works' "bleeding-edge" boutique design house was pitted against legendary aircraft manufacturer the Northrop Corporation. The rest is history, and as in the story of the Advanced Tactical Bomber program, the loser of the competition may have lost simply because their concept was too far ahead of their time.

By the later part of the 1970s the Skunk Works team was riding high after winning the XST competition, and was in the process of testing the resultant Have Blue flying technology demonstrator, the arrow-shaped aircraft that was based directly on their game-changing "Hopeless Diamond" computer model. Eventually the success of the Have Blue aircraft would morph into the F-117A Nighthawk Stealth Fighter, but there was one more major decision that the USAF would have to make before locking down the final design.

There were two "Advanced Tactical Aircraft" (ATA) proposals that the Skunk Works put forth to the USAF after winning the XST competition and testing Have Blue. The ATA-A was a fighter-sized aircraft with a 450-mile combat radius, one pilot and a payload of around 5,000lb. The ATA-B was a larger "regional bomber" that sported a 1,150-mile combat radius, and carried two crew members and 10,000lb of precision-guided weapons. The ATA-B was even pitched by the Skunk Works to be a potential replacement for the service's F-111 Aardvark swing-wing medium bombers. In the end, the USAF chose the less expensive and lower risk of the two options, the smaller ATA-A, as they wanted to be able to purchase enough of the jets on the black budget to make the program worthwhile. The result of this key decision was the F-117A Nighthawk as we know it today.

The Skunk Works management team, headed by legendary aircraft designer and grandfather of stealth design Ben Rich, soon went back to the USAF, in this case the Strategic Air Command, and pitched a tweaked version of their larger ATA-B stealth attack jet to them. The USAF, and the Carter Administration which had controversially canceled the B-1A program in part due to the aforementioned developments in stealth technology, had the same idea as Ben Rich. In fact the Carter Administration, a big believer in stealth technology's promise very early on, took a lot of heat for canceling the troubled B-1A and could not even explain to the press that they were going to focus on a new breakthrough game-changing technology, that being stealth, as it was so deeply classified at the time.

After a consensus was reached that a stealth bomber was strategically relevant and that it was actually possible to build one, the momentum for the program almost immediately began to build steam. To the Skunk Works' surprise, the USAF did not want something to replace the F-111, they wanted something to replace the recently sacked B-1A, and even the 1950s-vintage B-52. They wanted a big, long-range, hard-hitting, heavy bomber ... And they wanted it to be as invisible to radar as the diminutive Have Blue.

It was a new decade, and as the program that would become the Advanced Technology Bomber (ATB) moved on, two competitors emerged as the finalists for another winner-take-all stealth jet competition. The same arch rivals who competed for the XST program, Northrop and Lockheed's Skunk Works, would be facing off again, and this time around the stakes were huge, both physically and economically. The USAF wanted 132 stealth bombers in a production run that could last almost 20 years. Both competitors knew that whoever won this competition could theoretically "own" the USAF's heavy bomber portfolio from about 1990 well into the next millennium, and perhaps forever. With the sheer size of aircraft and the numbers that the USAF was demanding in mind, both teams paired with another manufacturer for production. Skunk Works teamed up with Rockwell, who had just lost the B-1A program, and Northrop teamed up with Boeing.

In the end, Northrop Grumman built a total of 21 B-2A Spirit stealth bombers, not the 132 they had envisioned when they fought a good battle to win the ATB contract.

SENIOR PROM ATCM

1980

PROGRAM: SENIOR PROM

Name: N/A

Mission: Tactical cruise missile

Length: 18ft 4in (5.59m)

Wing span: 12ft 6in (3.81m)

Height: 6ft 2in (1.88m)

Max T.O. Weight: 2,420lb (1,098kg)

Ferry Range: 2,000 miles (3,218km)

First Flight: 1 March 1980

Last Flight: 13 March 1981

Crew: Unmanned

Number Built: 9 total (7 flyable, 2 for static testing)

Power Plant: 1 x Williams F-107 turbofan

Design Speed: Mach 0.7 (519mph; 835km/h)

Service Ceiling: 55,000ft (16,764m)

Combat Radius: 2,000 miles (1,737nm; 3,218km)

Weapons Load: One warhead, either conventional or nuclear

In early 1976, the Skunk Works began to consider the application of stealth into different vehicles and missions. One of the most attractive programs was a stealthy Air Launched Cruise Missile (ALCM). Lockheed looked at small or short-range and ALCM-sized or long-range cruise missiles.

Following the success of the test program for the Have Blue stealth technology demonstrator aircraft, the Air Force awarded a contract to the Lockheed Skunk Works for the development of an unmanned aerial vehicle (UAV), intended to act as the prototype of a cruise missile, that would apply the Have Blue's faceted design in order to reduce the radar cross section (RCS) of the missile by deflecting the electromagnetic waves from radar transmitters away from their source, instead of directly back at the radar set's antenna.

The Senior Prom vehicle was intended to be expendable; however, it was modified to be reusable before testing commenced, with a ballistic recovery parachute and an inflatable landing bag located under the fuselage. The aircraft was powered by a single Williams turbofan engine, with the air intake and exhaust being configured in such a manner that the airframe would shield them from the ground, reducing the aircraft's radar and infrared signatures.

On 15 October 1977, Lockheed received the go-ahead for Phase II for the Advanced Tactical Cruise Missile or ATCM (Senior High I). It was not until October 1978 when the program was transferred from Wright Field to the Low Observable Special Projects Office (SPO) that the name changed to Senior Prom.

Phase II was tasked to design, develop and test a prototype configuration of an ATCM. A total of nine vehicle systems were to be produced, seven flyable and two for ground tests. A flight-test program was set up with a goal of ten successive and successful flights as the criterion, Since Lockheed was only building seven flyable systems, it was necessary to build a parachute recovery system, so that the vehicle could be reused (some of the vehicles were reused three times during the program). The overall objective of this phase was to ascertain the readiness of the ATCM for production (Phase III).

When Lockheed began the program, they had planned on a July 1979 first flight, but due to launch and recovery problems and redesign of the configuration the launch date was moved to 15 February 1980, which still was pretty good since it was only 24 months from go-ahead. The first successful launch was on 1 March 1980 and it did all that it was planned to achieve; however, the Senior Prom was lost due to a parachute failure. This was then followed with nine more successful flights. The overall time span of the ATCM prototype program was to be 34 months for Phase I and Phase II. It was actually completed in 38 months in spite of all the early problems. The program met the contractual objectives of development and flight-test of ten successful and successive flights, a precision flight control system, a radiometric area correlation guidance system, a modified engine and a production plan for full scale production.

As a part of the test program, Lockheed had to acquire a DC-130H, used to launch Senior Prom. The purpose of the DC-130 was to check out the launch, monitor the cruise and then execute the necessary recovery system. As a backup it was necessary to provide a ground system in a van, that would duplicate a ground system in the DC-130 if the ATCM should lose data link contact.

Senior Prom's RCS either met or favorably exceeded the predicted test. These tests were flown over the dynamic radar test range as well as against threat ground radars, F-15 fighters and an AWACS radar system. After a total of ten flights over the duration of the testing program, Senior Prom had met all of its objectives. The Senior Prom cruise missiles were reportedly capable of flying within 500ft of the Hughes SPS-13RCS validation radar without generating a discernible return. Most testing took place at Area 51 in south central Nevada, with a DC-130H acting as the launch aircraft. None of these systems were able to track Senior Prom. The new and refurbished vehicles were put into storage. Many proposals were later made to use these vehicles to test the capability of our latest ground tracking radars or the Navy's Aegis systems; however, due to politics and bureaucracy, nothing happened.

YF-117A SENIOR TREND

1981

PROGRAM: F-117A

Name: Senior Trend – Nighthawk

Mission: Stealth attack mission

Length: 65ft 11in (20.09m)

Wing Span: 43ft 4in (13.21m)

Height: 12ft 5in (3.78m)

Max T.O. Weight: 52,500lb (23,800kg)

First Flight: 18 June 1981

Last Flight: 22 April 2008 – Stored at Tonopah Test Range in Class 1000 storage

Crew: 1

Number Built: 64 (5 YF-117As and 59 F-117As)

Power Plant: 2 x General Electric F404-F1D2 turbofans

Design Speed: Mach 0.92 (617mph; 993km/h)

Service Ceiling: 45,000ft (13,716m)

Combat Radius: 1,070 miles (930nm; 1,720km)

Weapons Load: 2 x 2,000lb internal weapons

On 18 June 1981, at 6.05am Pacific Daylight Time (1.05pm UTC), the first full-scale development Lockheed YF-117A Nighthawk, 79-10780, made its first flight at the Groom Dry Lake test facility at Area 51, with Skunk Works test pilot Harold C. "Hal" Farley, Jr, at the controls. The super-secret airplane was made of materials that absorbed radar waves, and was built with the surfaces angled so that radar signals were deflected away from the source.

Hal Farley is a former US naval aviator who spent eight years testing F-14 Tomcat fighters for Grumman before going to work at Lockheed's Skunk Works. He flew the Have Blue proof-of-concept prototype and the Senior Trend F-117 program. When he retired from Lockheed, Farley had more that 600 flight hours in the F-117. His call sign is "Bandit 117."

Commonly called the "Stealth Fighter," the Nighthawk is actually a tactical bomber. Five developmental aircraft and 59 operational F-117As were built. They were in service from 1983 until 2008, when the Lockheed F-22 Raptor was planned to assume their mission. They are currently mothballed and could be returned to service if needed.

The F-117A Nighthawk is a single-seat, twin-engine tactical bomber with swept wings and tail surfaces. It is 65ft 11in long with a wing span of 43ft 4in and height of 12ft 5in.

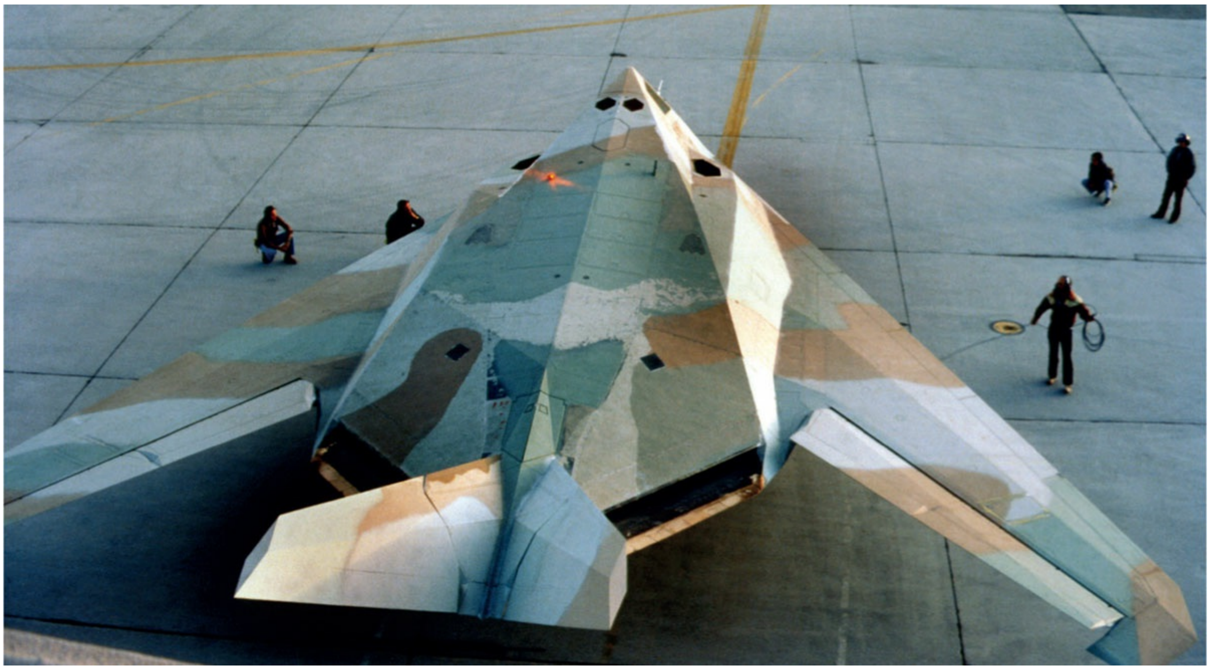
The F-117 was born after combat experience in the Vietnam War when increasingly sophisticated Soviet surface-to-air-missiles downed heavy bombers. It was a black project, an ultra-secret program for much of its life until 22 November 1988.

The success of Have Blue led the government to increase funding for stealth technology. Much of that increase was allocated towards the production of an operational stealth aircraft, the Lockheed Martin F-117A, under the program code name Senior Trend.

The decision to produce the F-117A was made on 1 November 1978, and a contract was awarded to Lockheed Advanced Development Projects. Ben Rich led the program and called on Bill Schroeder, a Lockheed mathematician, and Denys Overholser, a computer scientist, to explore Pyotr Yakovlevich Ufimtsev's work. Ufimtsev is a Soviet/Russian physicist and mathematician, considered the seminal force behind modern stealth aircraft technology.

The three designed a computer program called "Echo," which made it possible to design an airplane with flat panels, called facets, which were arranged so as to scatter over 99 percent of a radar's signal energy, "painting" the aircraft.

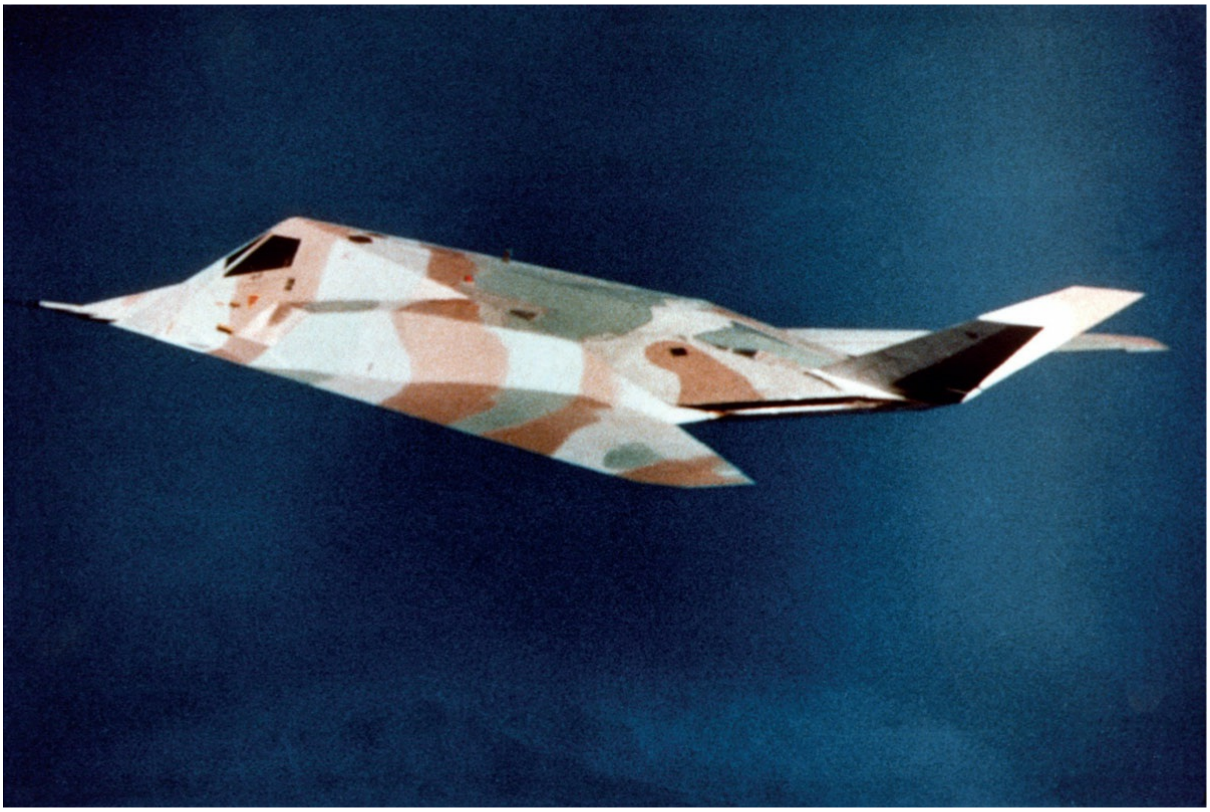
The first YF-117A, serial number 79-0780, made its maiden flight from Area 51 on 18 June 1981, only 31 months after the full-scale development decision. The first production F-117A was delivered in 1982, and operational capability was achieved in October 1983. The Air Force denied the existence of the aircraft until 1988, when a grainy photograph was released to the public. On 21 April 1990 two F-117As were flown to Nellis AFB, Nevada, from Tonopah Test Range base in Nevada, arriving to a crowd of tens of thousands of very excited aviation journalists and reporters.



Early flight-test YF-117As were painted in a distinctive four-color camouflage and without any national insignia. All F-117As that the world saw were painted black. (Author's collection)

Hal Farley, photographed as he exits the first of five full-scale development YF-117As. (Author's collection)

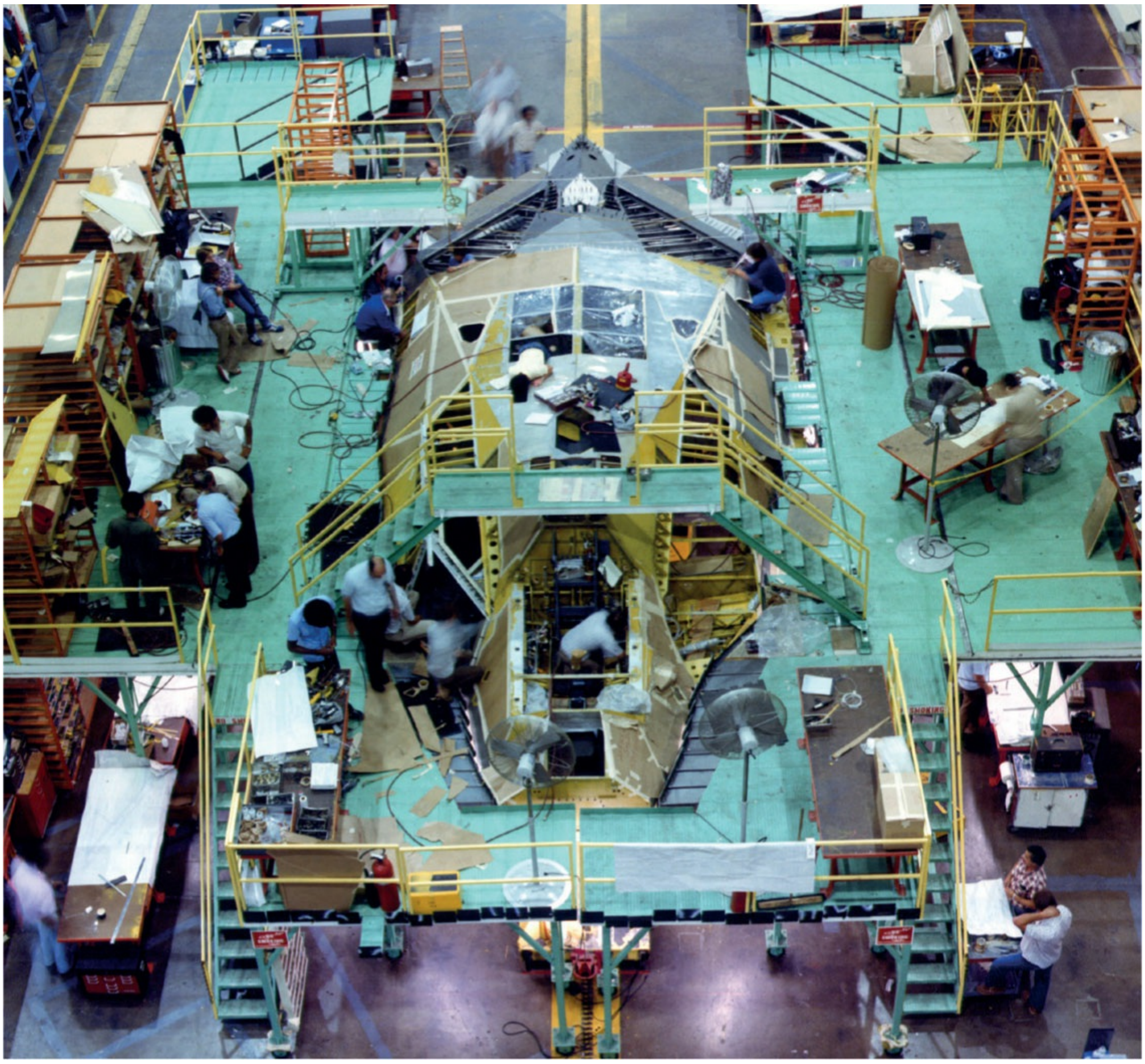
An aerial view of the Tonopah Test Range base about 20 miles east-southeast of the town of Tonopah, located about 200 miles north of Las Vegas, NV. The photo was taken at 10,000ft in a Cessna 150 on 10 December 1993. (James C. Goodall)



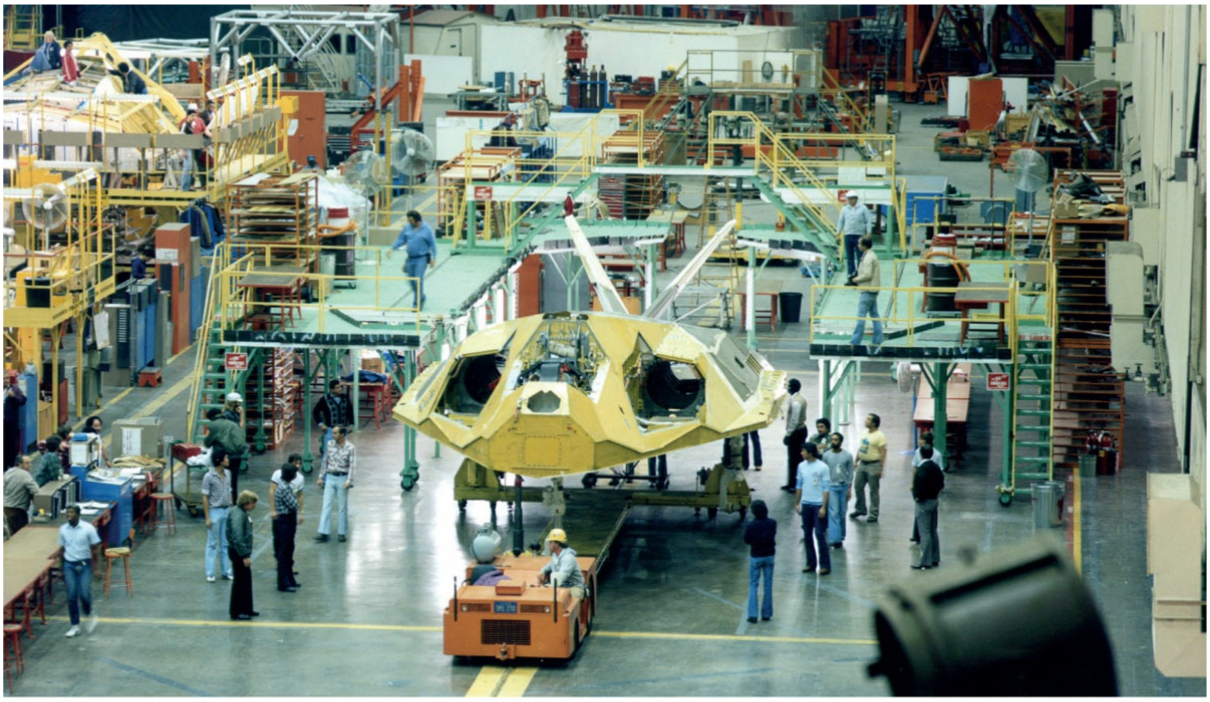
The first flight of the YF-117A, full-scale development F-117A 79-10780, occurred on 18 June 1981 from the Area 51 South base. (Author's collection)

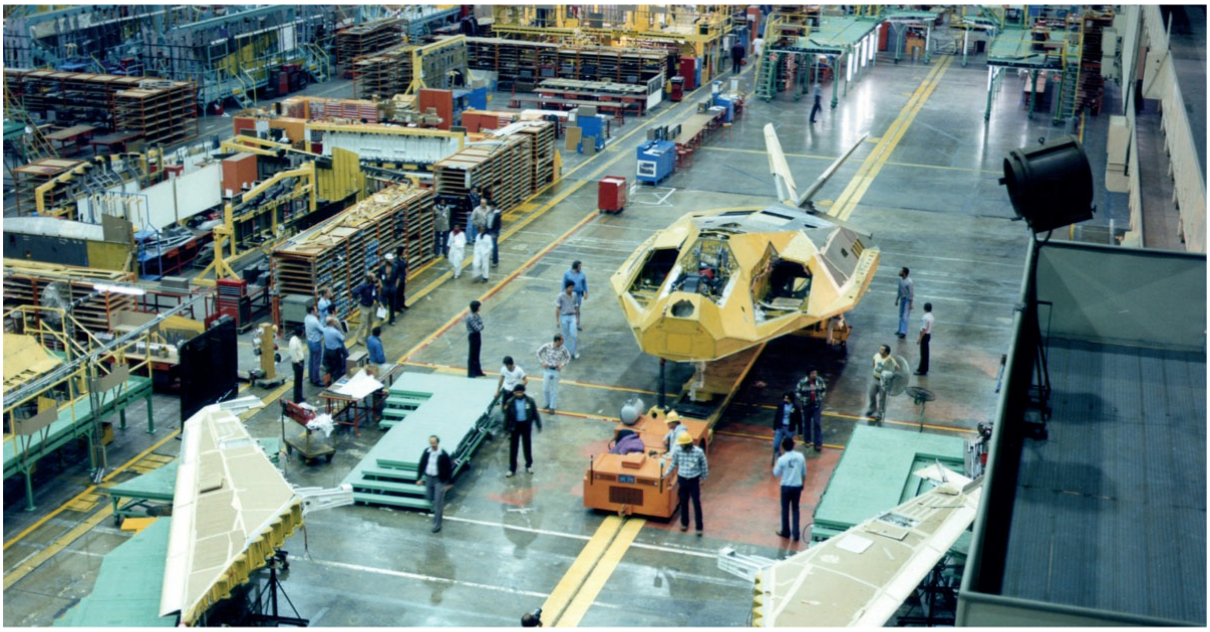
Hal Farley poses in front of the YF-117A immediately after his historic first flight on 18 June 1981. The F-117A was supposed to have flown in the summer of 1978, but technical difficulties lead to the delay. (Author's collection)

This F-117A, 85-0816, was assigned to the commander of the 7th Fighter Squadron, 49th Fighter Wing. Here it flies over the dedicated two-place F-117 hangars at Holloman AFB. (USAF)

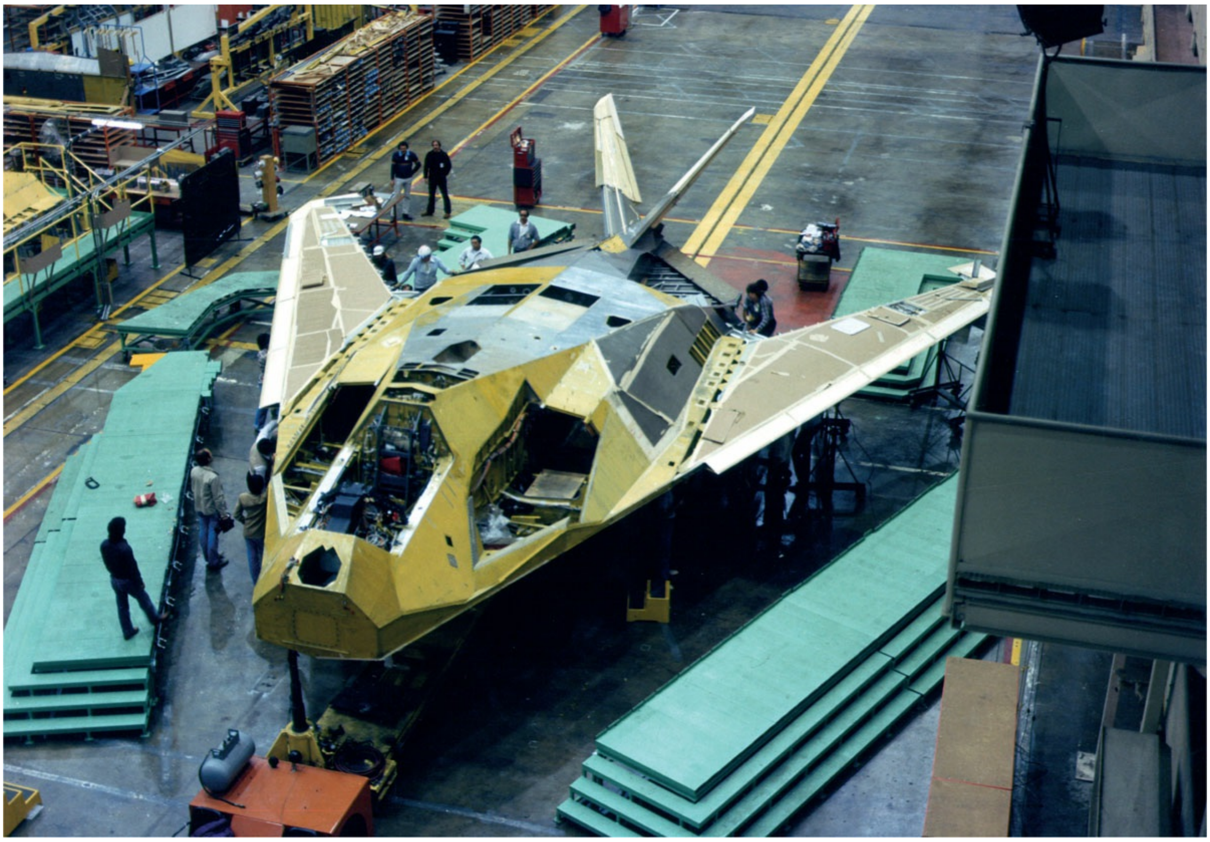


The F-117A Nighthawk stealth attack aircraft was developed in near-complete secrecy. This aircraft was one of five pre-production aircraft that were flown to test performance, stability and control, and mission systems. The test aircraft were all airlifted to the test site via C-5, departing Burbank in the middle of the night. Construction of the YF-117A prototypes and all of the F-117A production aircraft occurred at Lockheed's Burbank production facility. In this photo, the very first YF-117A fuselage is surrounded with work platforms and production tooling as it is prepared to move through the assembly line. (Lockheed Martin)

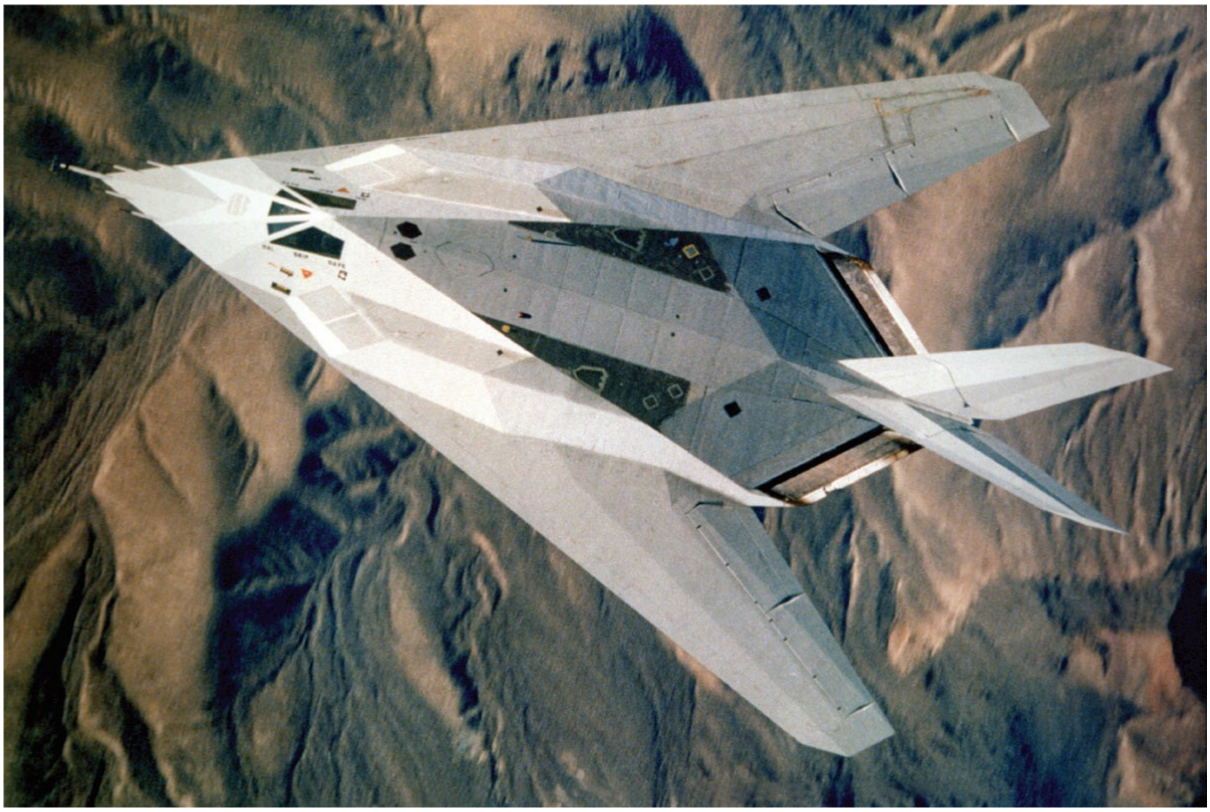




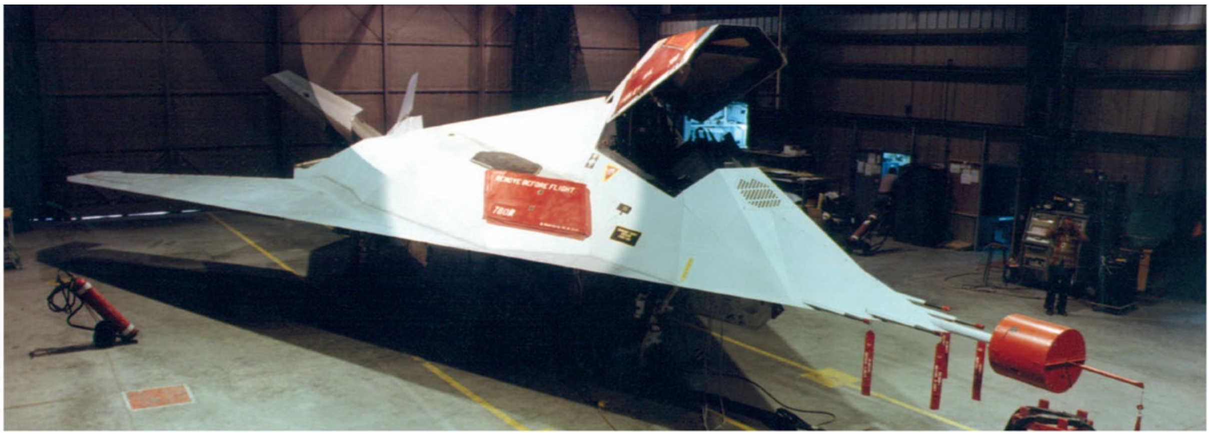
Free of the production tools and jigs, the first airframe moves down the assembly line in preparation for attaching the wings. (Lockheed Martin)

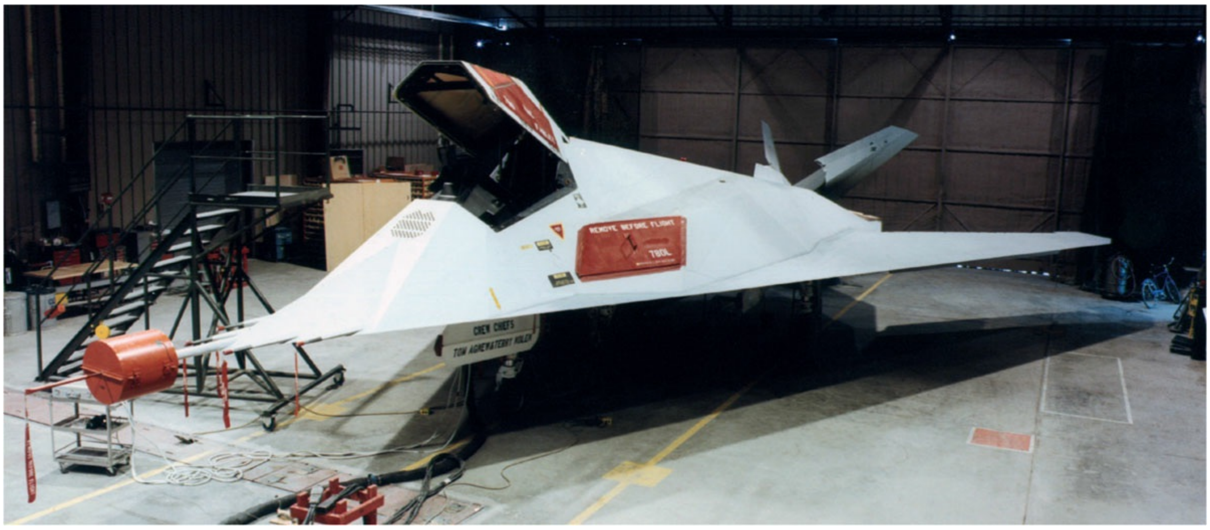


The FSD YF-117A sports its newly attached wings. The light green work platforms will be moved next to the aircraft, allowing the Lockheed production team to complete the installation of the inlets, cockpit, nose assembly, leading edges and control surfaces and to begin systems integration and testing. (Lockheed Martin)

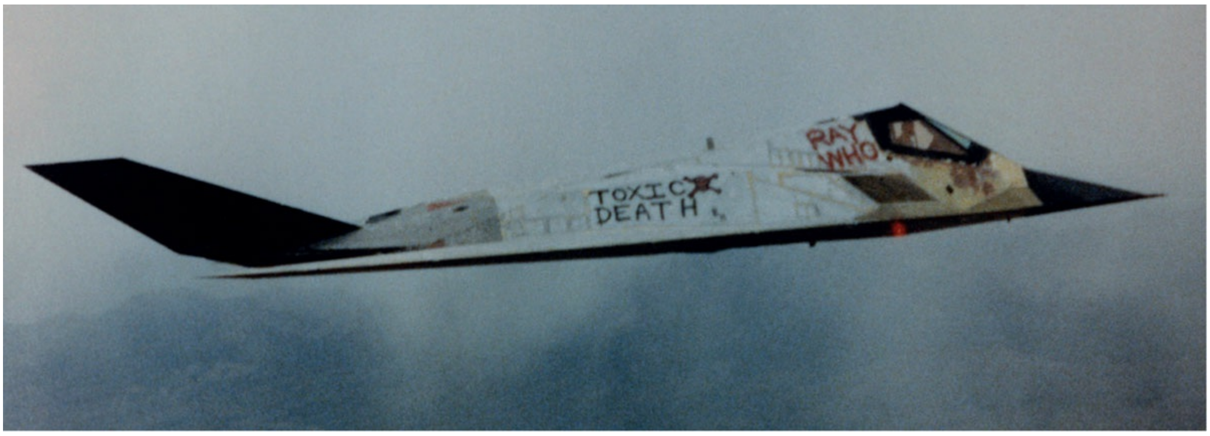


Piloted by Lockheed test pilot Hal Farley, YF-117A 780 is photographed on its maiden flight on 18 June 1981 with a new light ghost gray paint scheme. Also to note is the center-mounted test probe that it used during early test flights. (Lockheed Martin)

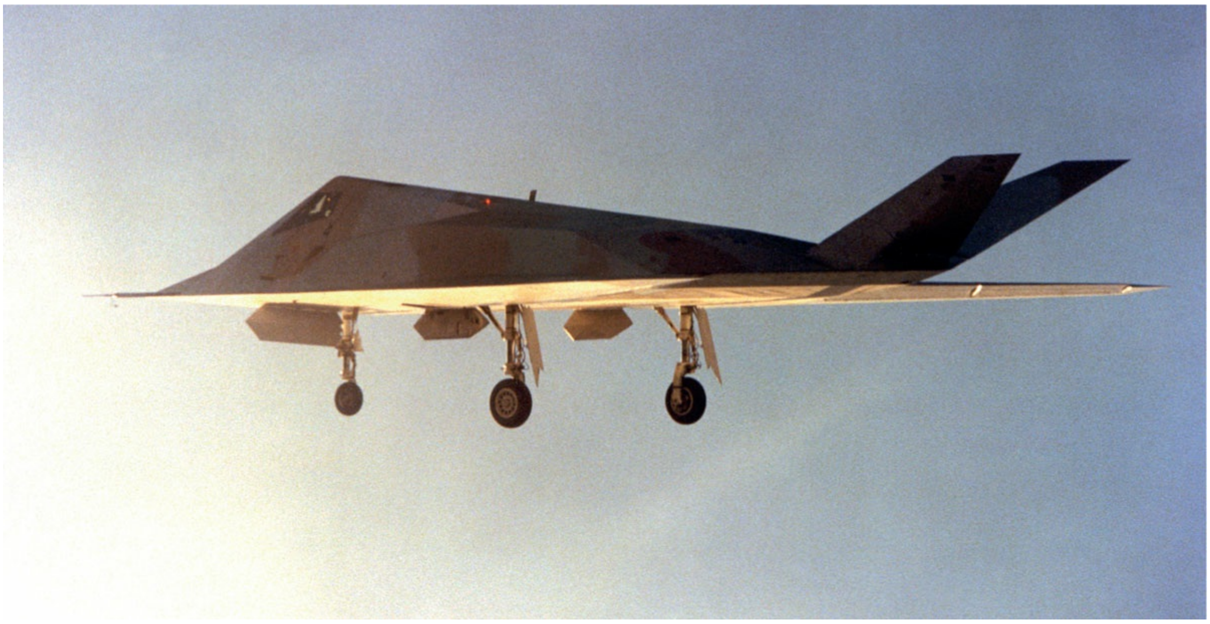




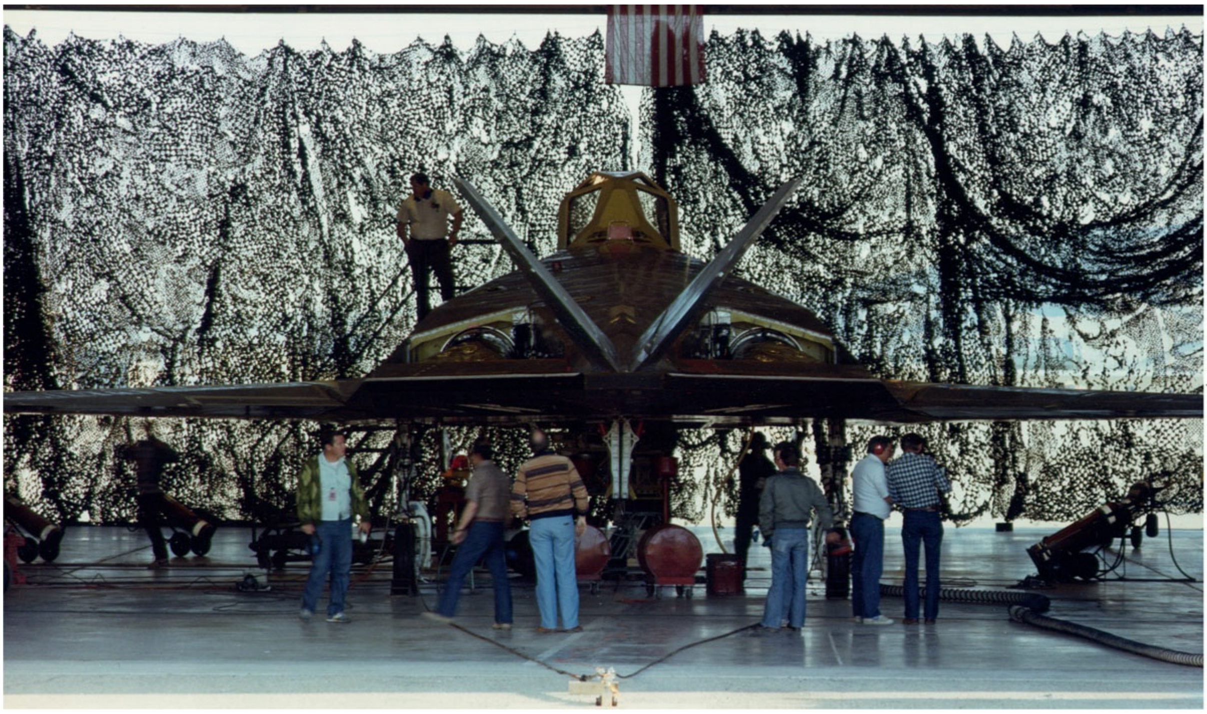
A photo of "Scorpion 1" in the hangar complex at the south side of the Area 51 flight complex. In this view there are no other markings with the exception of the red "ejection seat" triangles on either side of the cockpit. (Lockheed Martin)



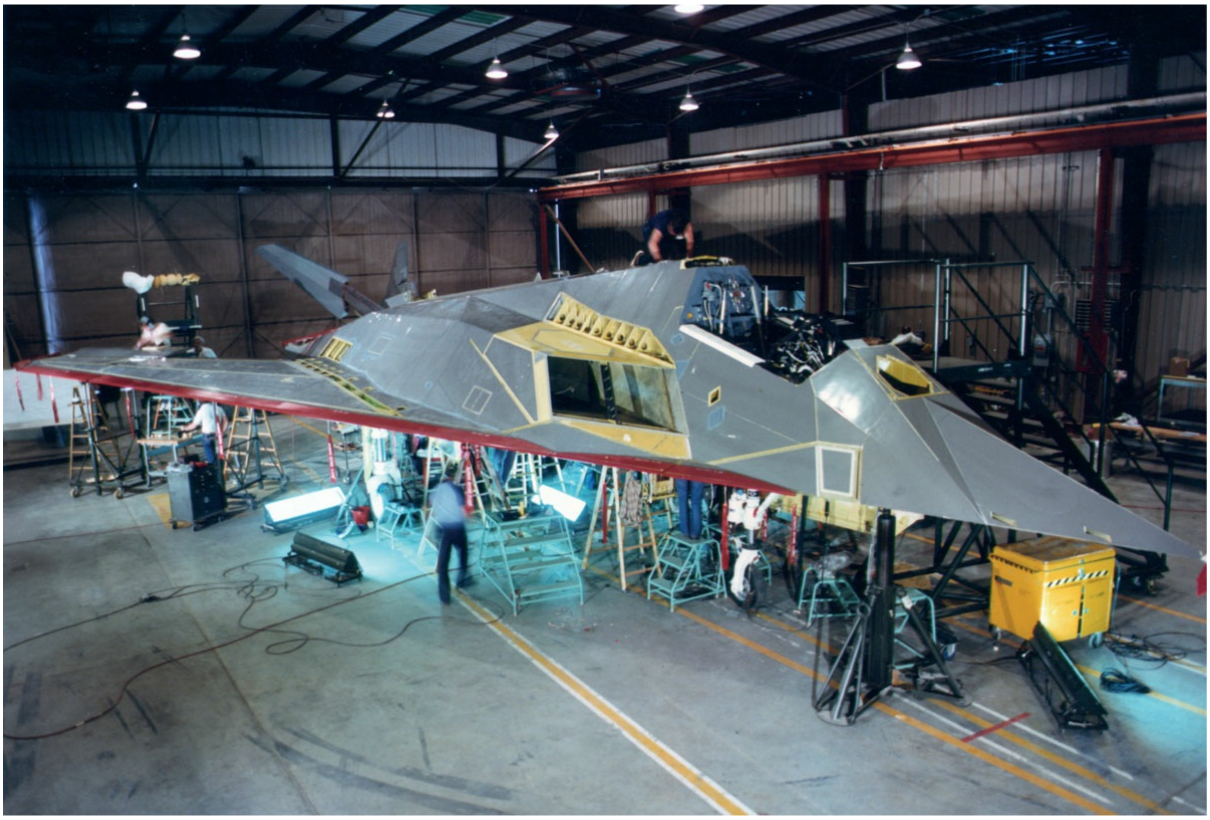
On its way to the National Museum of the Air Force, the second YF-117A full-scale development F-117A takes to the air missing its very distinctive "black" paint scheme; the crew at Lockheed pulled a prank with this graffiti-covered YF-117. (Lockheed Martin)



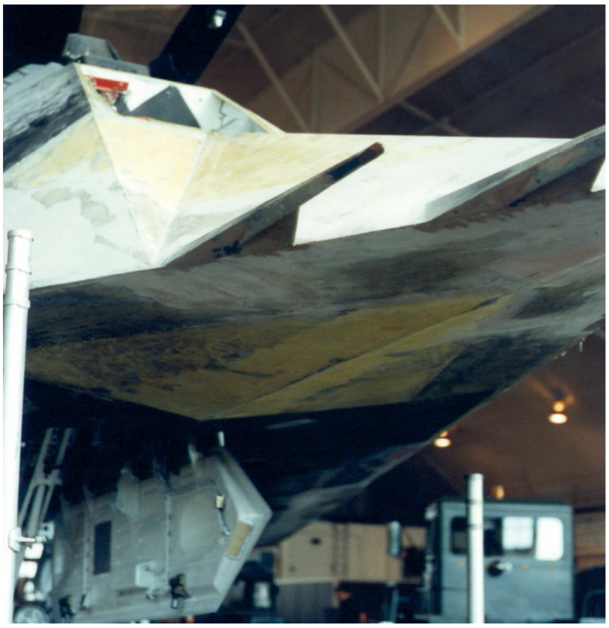
The first YF-117 on final approach to the 14,000ft-long Area 51 runway as the sun hangs low in the late afternoon sky. Area 51 is also known as Detachment 3 of the Air Force Test Center out of Edwards. (Author's collection)



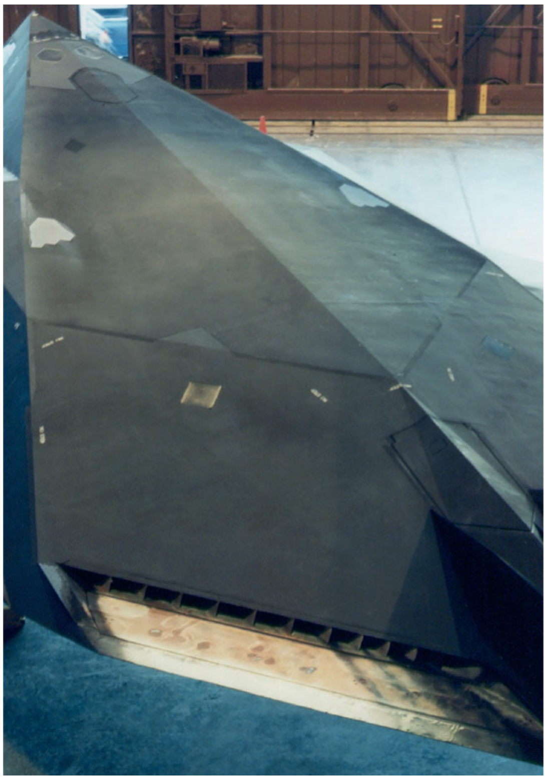
If you look closely, the F-117A's "platypus" exhaust ejectors have been removed or not yet installed. The camouflaged netting in front of the opened hangar door is to keep prying eyes from seeing what is behind the curtain. Just because a person works at Area 51 doesn't mean they are cleared to see everything on the base. (Lockheed Martin)



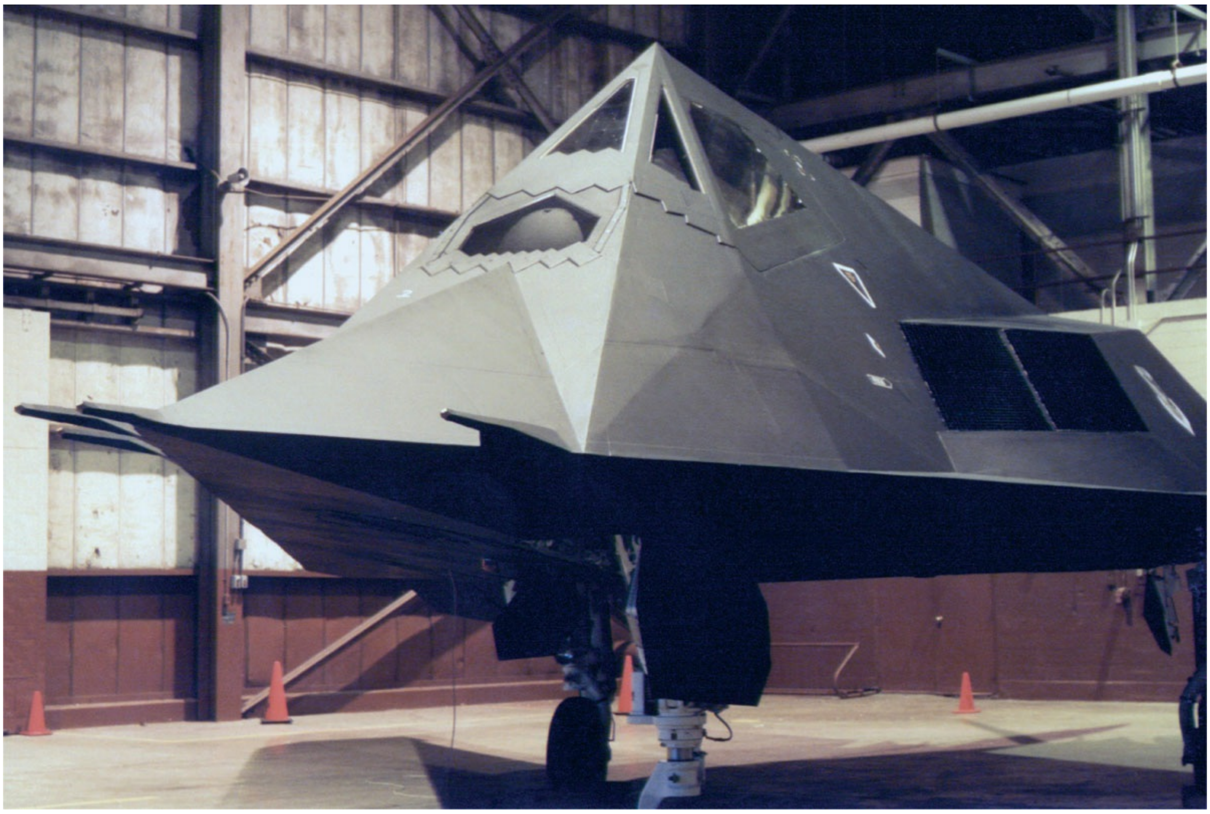
The first YF-117A, 780, is undergoing reassembly after being moved from Burbank to Area 51 via Air Force C-5As. The aircraft is shown in Hangar 14 at the south end of the Area 51 complex and in the same hangars that housed the A-12 during their time at Area 51. The red coverings on the leading edge of the wing are in place to protect it from possible damage during assembly and maintenance. (Lockheed Martin)



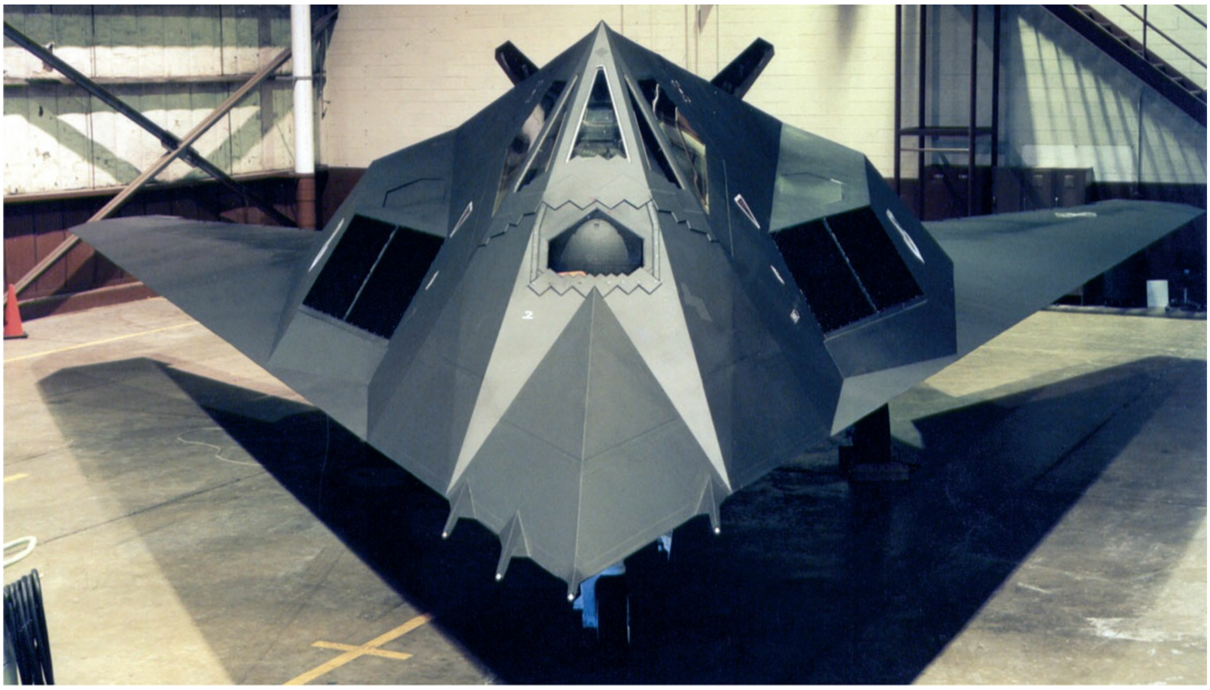
It’s not very often that one gets to see an F-117A without its RAM and stripped of all its coatings. This is the YF-117A that was assigned to the National Museum of the Air Force (NMUSAF) prior to being moved to the museum’s main gallery so that the general public could see at first hand the very first operational stealth fighter. (Author’s collection)



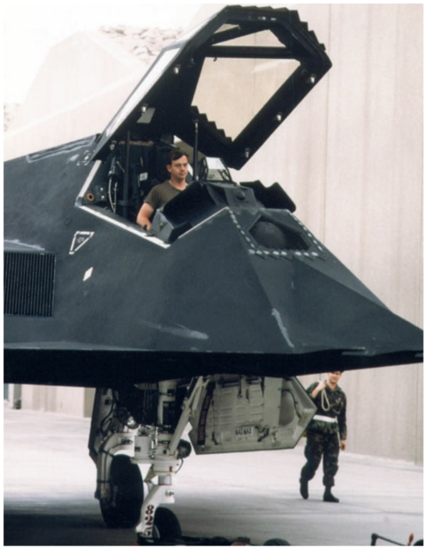
Until the author took this photo, there were no shots showing the makeup and layout of the unique F-117A "platypus" and the "shuttle"-like tiles that help dissipate the exhaust plume. (James C. Goodall)



The Air Force guard made clear to the author that he could enter the hangar, but he could not touch the aircraft. This East Coast "Air Show" F-117A was as clean as any F-117A that he has ever seen. (James C. Goodall)



A nose-on shot of the same "Air Show" F-117A. (James C. Goodall)

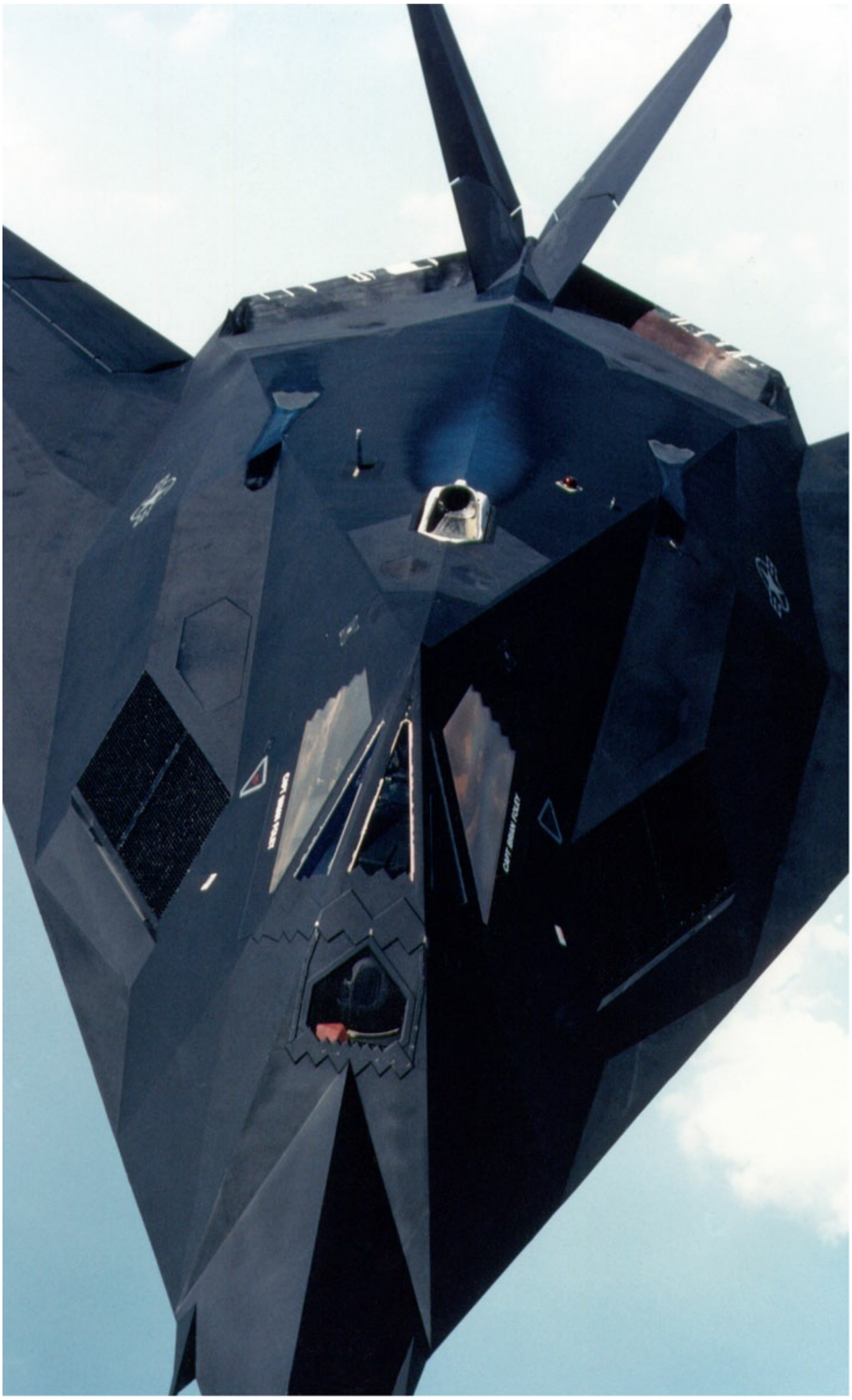


An Air Force ground crew mans the brakes on this F-117A, 825, in country during the buildup to Operation Desert Storm located in southwest Saudi Arabia. (USAF)

49 FW
HO
12 AF
10466
U.S.AIR FORCE

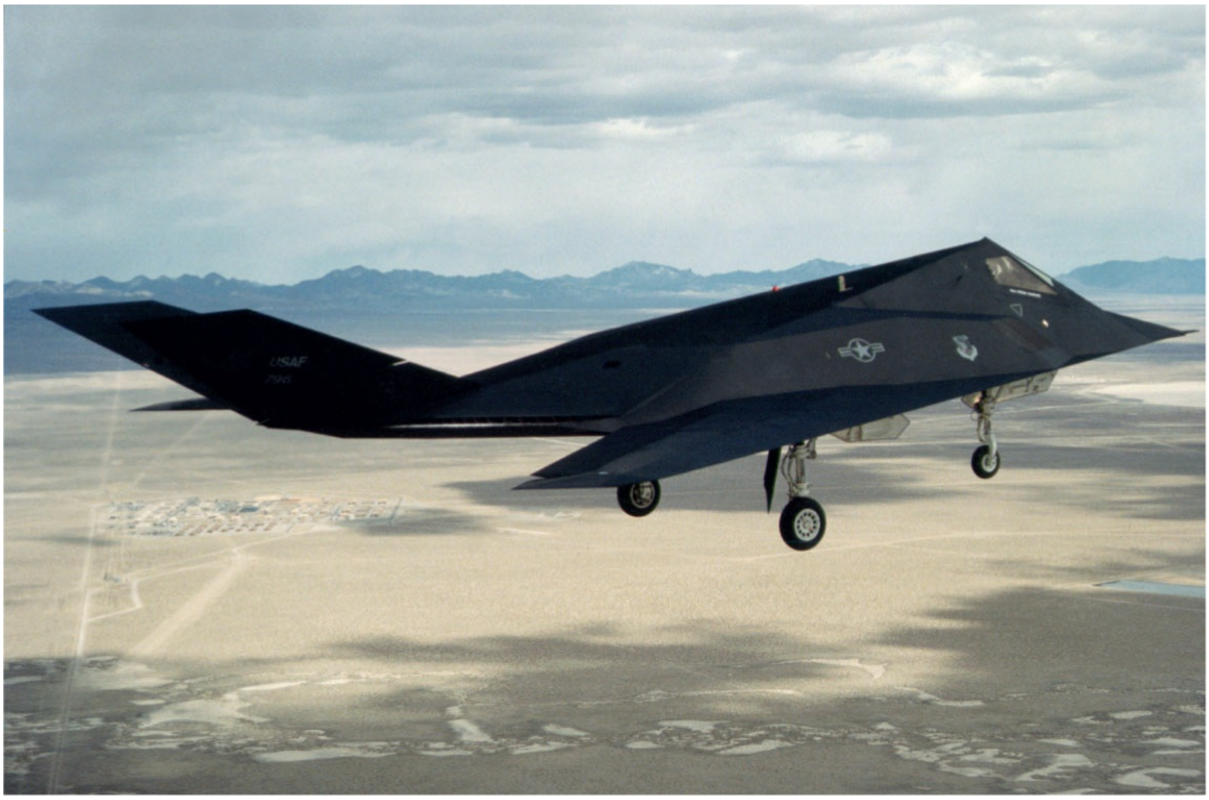
A Holloman-assigned T-38 is used as an in-flight chase to make sure that this very valuable stealth asset comes home all in one piece. Almost all F-117A flights out of Tonopah Test Range were accompanied by a T-38 chase plane. (USAF)

At the end of flight operations for Desert Storm, the public was allowed to see the F-117A return home to a rousing crowd at Nellis AFB, NV, on 1 April 1991. (James C. Goodall)



This F-117A is on its way to southwest Saudi Arabia at the beginning of Desert Shield in the early part of November 1990. As can be seen in the photo, taken from the boom operator's position, this F-117A had just disconnected from the KC-135R. (Author's collection)

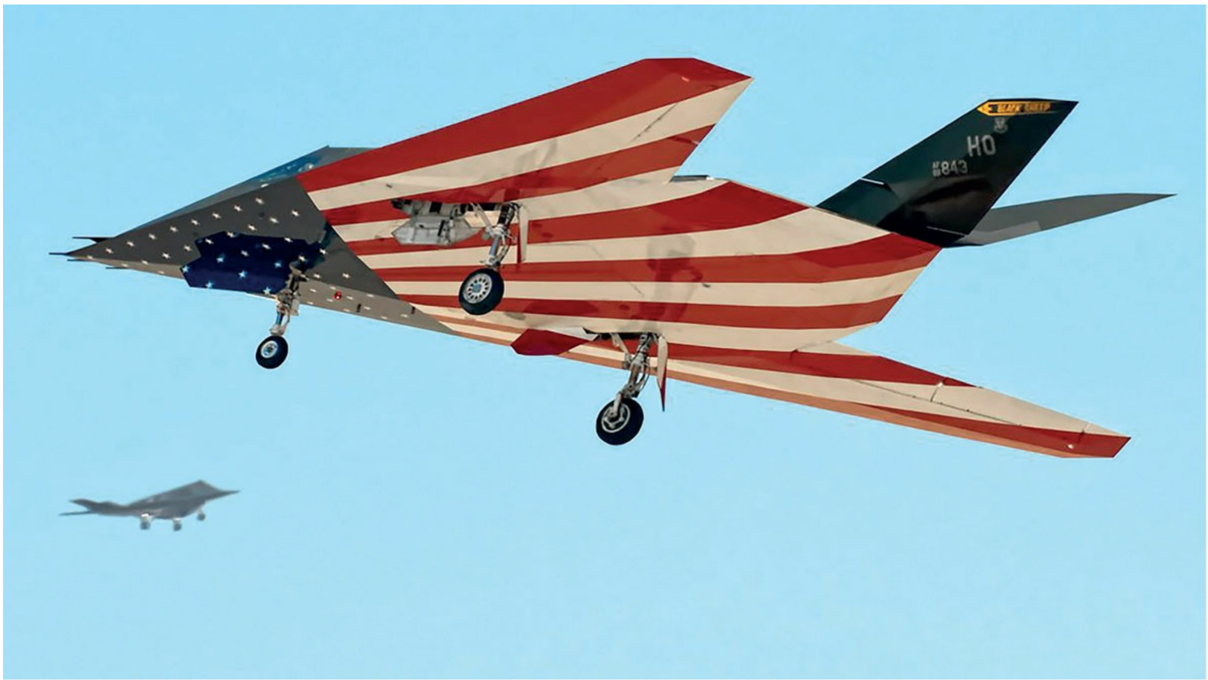
A Holloman-based F-117A does a fast fly-by at an airshow in the mid-1990s. (Author's collection)



An F-117A on approach to Tonopah Test Range base with the "Man Camp" billeting area about eight miles from the main base. (USAF)

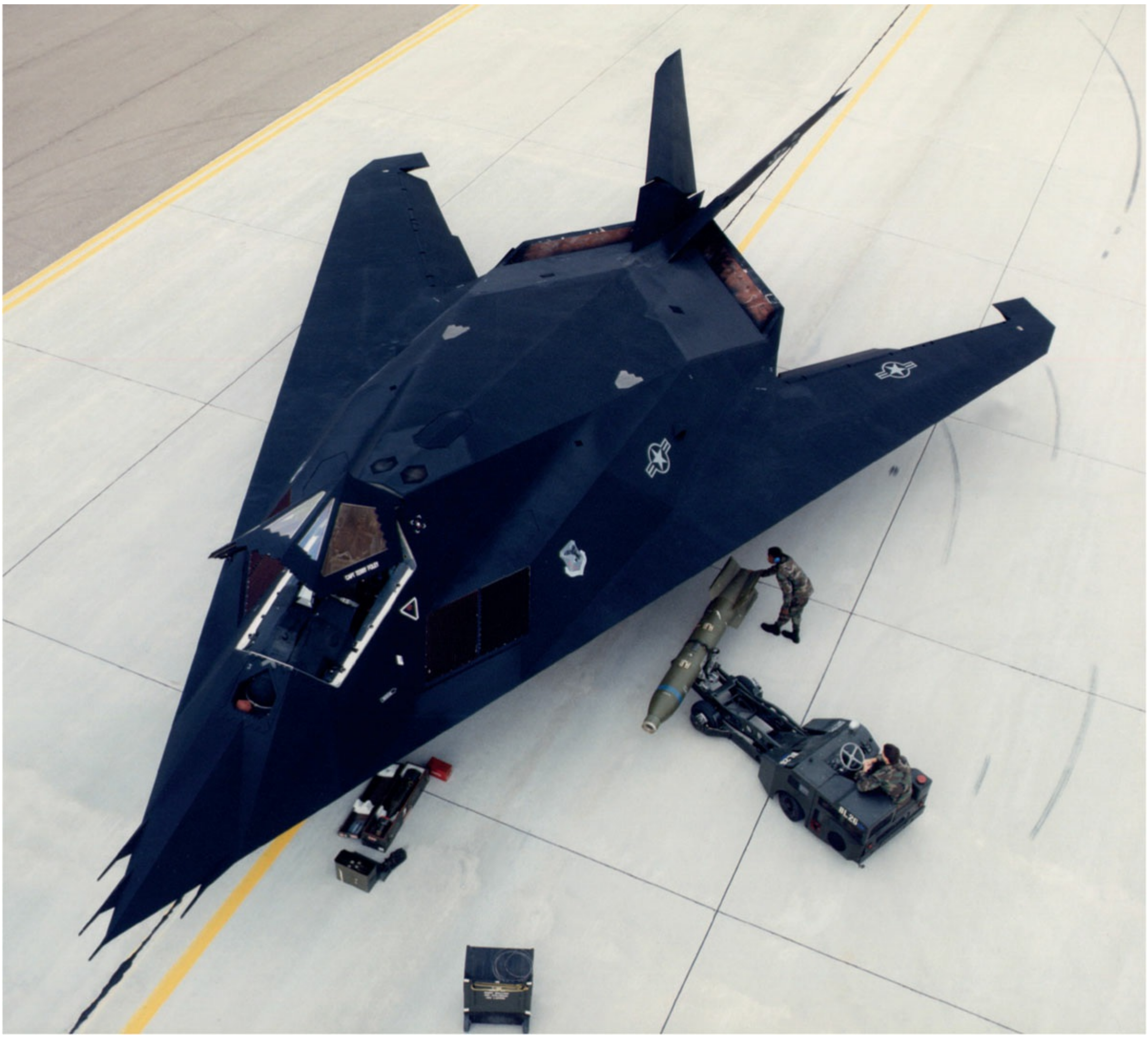
Two specially painted F-117A Nighthawks fly on one of their last missions. The F-117As were retired in a farewell ceremony at Wright-Patterson AFB, OH, on 22 April 2008. (USAF)

A Nellis-based F-117A carrying a WA tail code indicating that it was assigned to Detachment 1 of the 57th Wing at Holloman. The tail code is assigned to the Air Force Warfare Center (formerly the 53rd Test and Evaluation Group). (Author's collection)

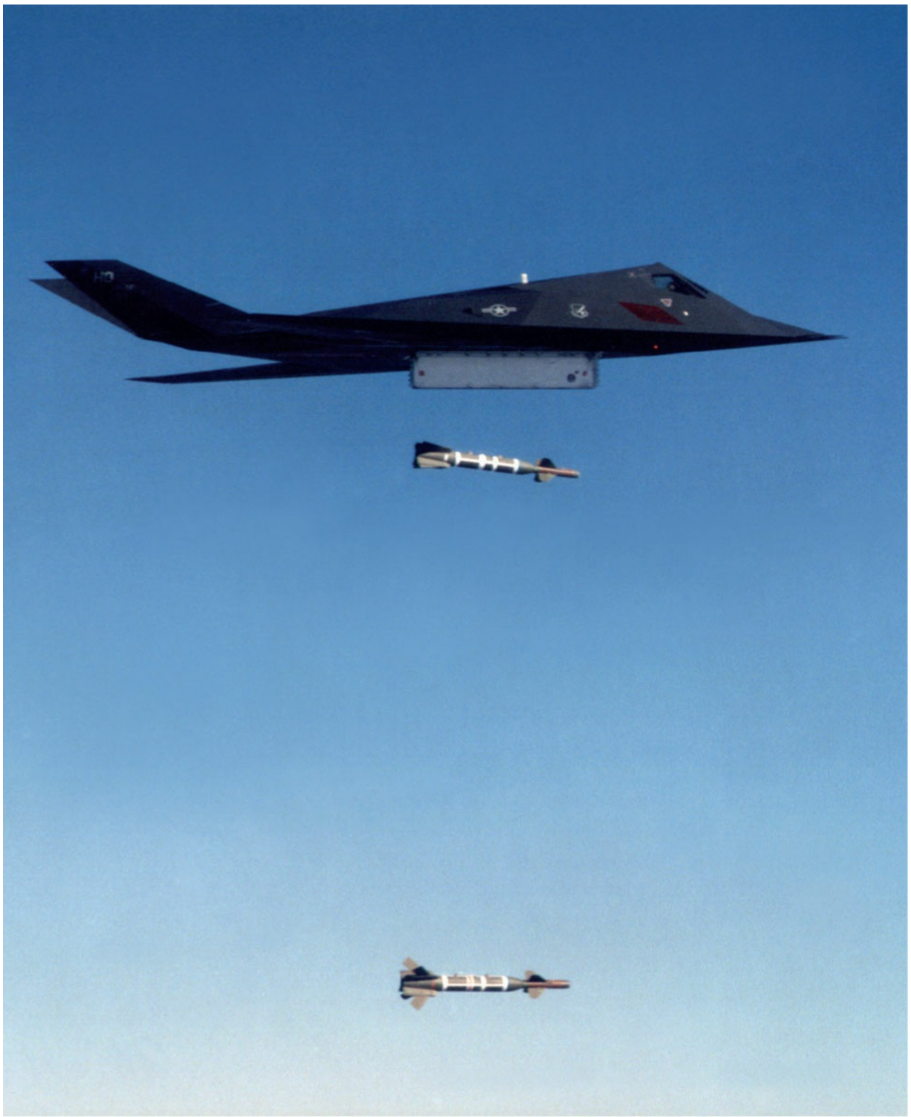


This was photographed at "BJ's Corner" doing touch-and-goes at Air Force Plant 42, Palmdale, CA. (Jim Mumaw)

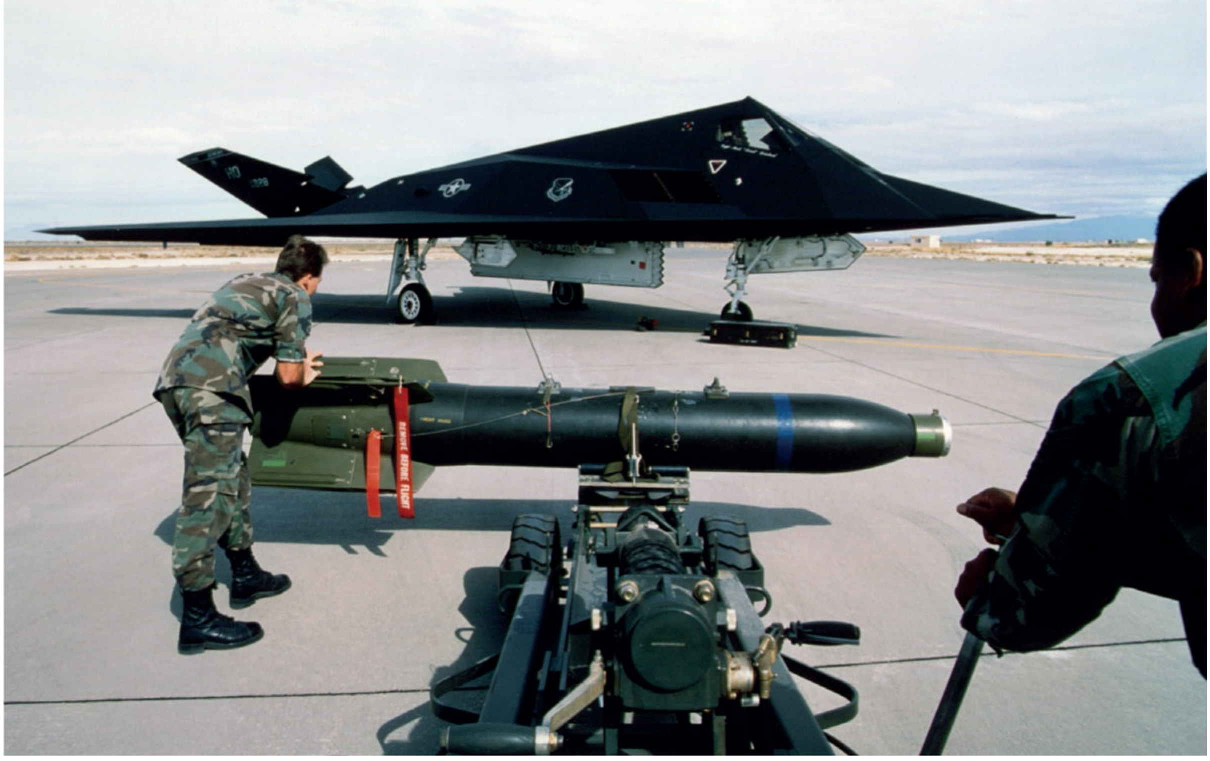
Ground crews prepare to move the 37th Tactical Fighter Wing (Provisional) F-117A next to the hardened shelters at the King Khalid AB in extreme southwest Saudi Arabia. (USAF)



Ground crewmen use an MJ-1 lift truck to load a GBU-27 LGB in the port side bomb bay of this Tonopah-assigned F-117A. (Author's collection)



A 49th Fighter Wing F-117A is shown releasing two GBU-27 2,000lb laser guided bombs (LGB) over the Nellis Range. (Author's collection)



Air Force weapons crewmen transport a 2,000lb inert practice GBU-27 LBG to the 49th Fighter Wing F-117A, 84-0828, at Holloman AFB. The "blue" band around the weapons forward section denotes that it is an inert practice weapon. (USAF)

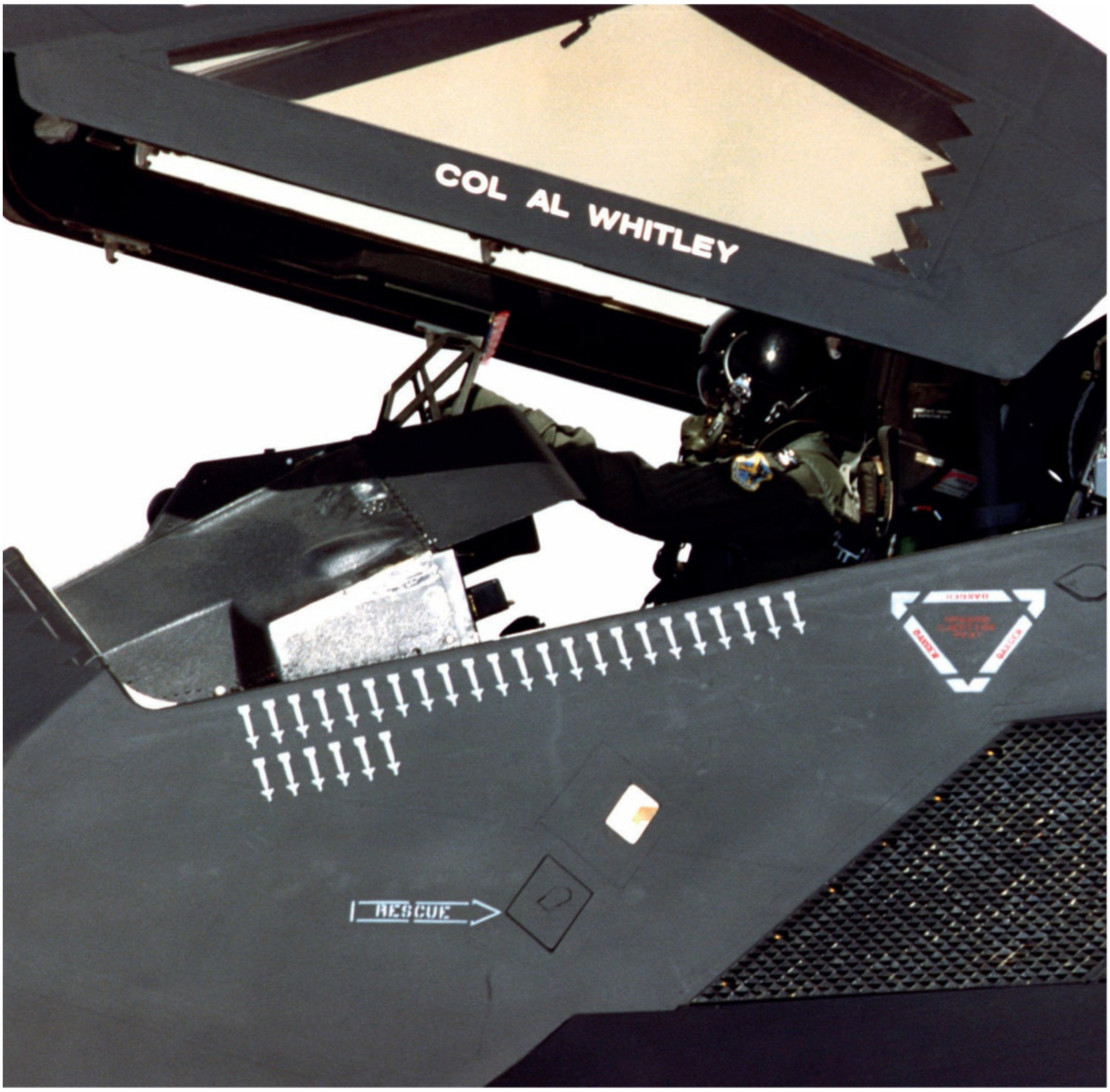
REMOVE BEFORE FLIGHT
BEFORE FLIGHT
BEFORE FLIGHT

An Air Force weapons loader (referred to by some as a 462) loads a GBU-27 into the F-117A's port weapons bay. The two perforated plates just in front of the GBU's seeker are wind deflectors and aid in the proper release of the weapon. (USAF)

Another view of the F-117A ground crews preparing to move the 37th Tactical Fighter Wing (Provisional) F-117A next to the hardened shelters at King Khalid AB in extreme southwest Saudi Arabia. The F-117 is compatible with most Air Force ground handling equipment; here it is being towed with a standard aircraft tow bar. (USAF)

Deployed members of the 8th Fighter Squadron, the "Black Sheep," pose in front of the 49th Fighter Wing's commander's F-117A at Ahmed Al-Jaber AB in Kuwait in 1998. (Greg L. Davis/USAF)

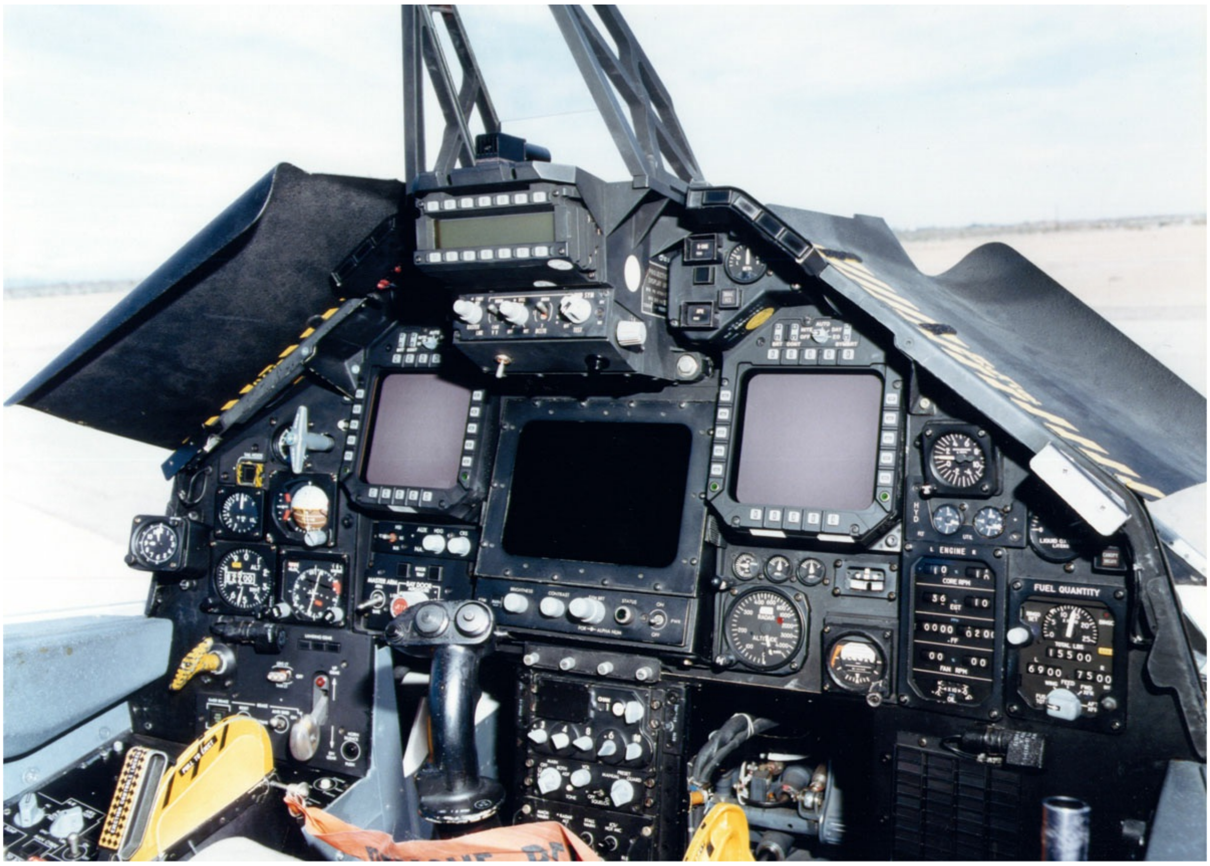
A lot of F-117A on "Home Coming Day" at Nellis on 1 April 1991 when the F-117As returned from their victories in Desert Storm. (James C. Goodall)


COL AL WHITLEY
RESCUE

A closeup of the 37th Tactical Fighter Wing commander, Col Al Whitley, with his F-117A 843 sporting 29 mission marks beneath the canopy sill. (James C. Goodall)

TFW
USAF
813
TR
USAF
830
USAF
810

The F-117A Desert Storm "Home Coming" for the 37th Tactical Fighter Wing was held at Nellis AFB on 1 April 1991. On display are six of the eight F-117A tails, some carrying tail code "TR" for the Tonopah-based F-117s. (James C. Goodall)



The office of the F-117A. The black shields lift up to allow easier access in and out of the cockpit. The glare shields keep the light from inside the cockpit to a minimum during a nighttime bombing mission. (USAF)

YF-22 ATF

1990

PROGRAM: YF-22

Name: Advanced Tactical Fighter/Raptor

Mission: Technology demonstrator for the F-22A

Length: 64ft 6in (19.66m)

Wing Span: 43ft (13.1m)

Height: 17ft 9in (5.41m)

Max T.O. Weight: 62,000lb (28,120kg)

First Flight: 29 September 1990 for PAV-1

Last Flight: 23 April 1991

Crew: 1

Number Built: 2

Power Plant: PAV-1: 2 x Pratt & Whitney YF119-PW-100 turbojets; PAV-2: General Electric YF120

Design Speed: Mach 2.2 (1,450mph; 2,335km/h)

Service Ceiling: 65,000ft (19,800m)

Combat Radius: 800 miles (695nm; 1,290km)

Weapons Load: None for flight-test

In 1981, the USAF developed a requirement for an Advanced Tactical Fighter (ATF) as a new air superiority fighter to replace the F-15 Eagle and F-16 Fighting Falcon. This was made more crucial by the emerging worldwide threats, including development and proliferation of Soviet MiG 29 and Su-27 Flanker-class fighter aircraft. It would take advantage of the new technologies in fighter design on the horizon including composite materials, lightweight alloys, advanced flight control systems, more powerful propulsion systems and stealth technology. In September 1985, the Air Force sent out technical requests for proposals (RFPs) to a number of aircraft-manufacturing teams. Seven bids were submitted in July 1986, and two companies, Lockheed and Northrop, were selected on 31 October 1986. The two teams, Lockheed/Boeing/General Dynamics and Northrop/McDonnell Douglas, undertook a 50-month demonstration phase, culminating in the flight-test of both teams' prototypes, the YF-22 and the YF-23.

The YF-22 was designed to meet USAF requirements for survivability, supercruise, stealth and ease of maintenance. Because Lockheed's submission was selected as one of the winners, the company, through its Skunk Works division, assumed leadership of the program partners. It would be responsible for the forward cockpit and fuselage, as well as final assembly at Palmdale. Meanwhile, Boeing would build the wings and aft fuselage, with the center fuselage, weapons bays, tail and landing gear built by General Dynamics. Compared with its Northrop/McDonnell Douglas counterpart, the YF-22 had a more conventional design; its wings had larger control surfaces, such as full-span trailing edges, and, whereas the YF-23 had two tail surfaces, the YF-22 had four, which made it more maneuverable. Two examples of each prototype air vehicle (PAV) were built for the Demonstration/Validation phase: one with General Electric YF 120 engines, the other with Pratt & Whitney YF119 engines.

The YF-22 was given the unofficial name Lightning II after Lockheed's World War II-era fighter, the P-38 Lightning; this persisted until the mid-1990s when the USAF officially named the aircraft Raptor. The F-35 later received the Lightning II name in 2006.

The first YF-22, PAV-1, serial number 87-0700, N22YF, with the General Electric YF120, was rolled out on 29 August 1990 and first flew on 29 September 1990, taking off from Air Force Plant 42, Palmdale, piloted by David Ferguson. During the 18-minute flight, PAV-1 reached a maximum speed of 250 knots and a height of 12,500ft, before landing at Edwards AFB.

Following the flight, Ferguson said that the remainder of the YF-22 test program would be concentrated on the maneuverability of the airplane, both supersonic and subsonic. The second YF-22, PAV-2, serial number 87-0701, N22YX, with the Pratt & Whitney YF119, made its maiden flight on 30 October 1990 at the hands of Tom Morgenfeld.

During the flight-test program, unlike that of the YF-23, weapon firings and high (60 degrees) angle of attack (AoA, or high-alpha) flights were carried out on the YF-22. Though not a requirement, the aircraft fired AIM-9 Sidewinder and AIM-120 AMRAAM missiles from internal weapon bays. Flight-testing also demonstrated that the YF-22 with its thrust-vectoring nozzles achieved pitch rates more than double that of the F-16 at low-speed maneuvering. The first prototype, PAV-1, achieved Mach 1.58 in supercruise, while PAV-2 reached a maximum supercruise speed of Mach 1.43; maximum speed was in excess of Mach 2.0. Flight-testing continued until 28 December 1990, by which time 74 flights had been completed and 91.6 airborne hours accumulated. Following flight-testing, the contractor teams submitted proposals for ATF production.

On 23 April 1991, Secretary of the Air Force Donald Rice announced the winner of the ATF competition as the YF-22. The YF-23 design was stealthier and faster, but the YF-22 was more agile. It was speculated in the aviation press that the YF-22 was also seen as more adaptable to the Navy's Navalized Advanced Tactical Fighter (NATF), but the US Navy abandoned NATF by 1992. Following the competition, PAV-1 was retired, but PAV-2 flew further sorties, amassing another 61.6 flying hours during 39 flights.

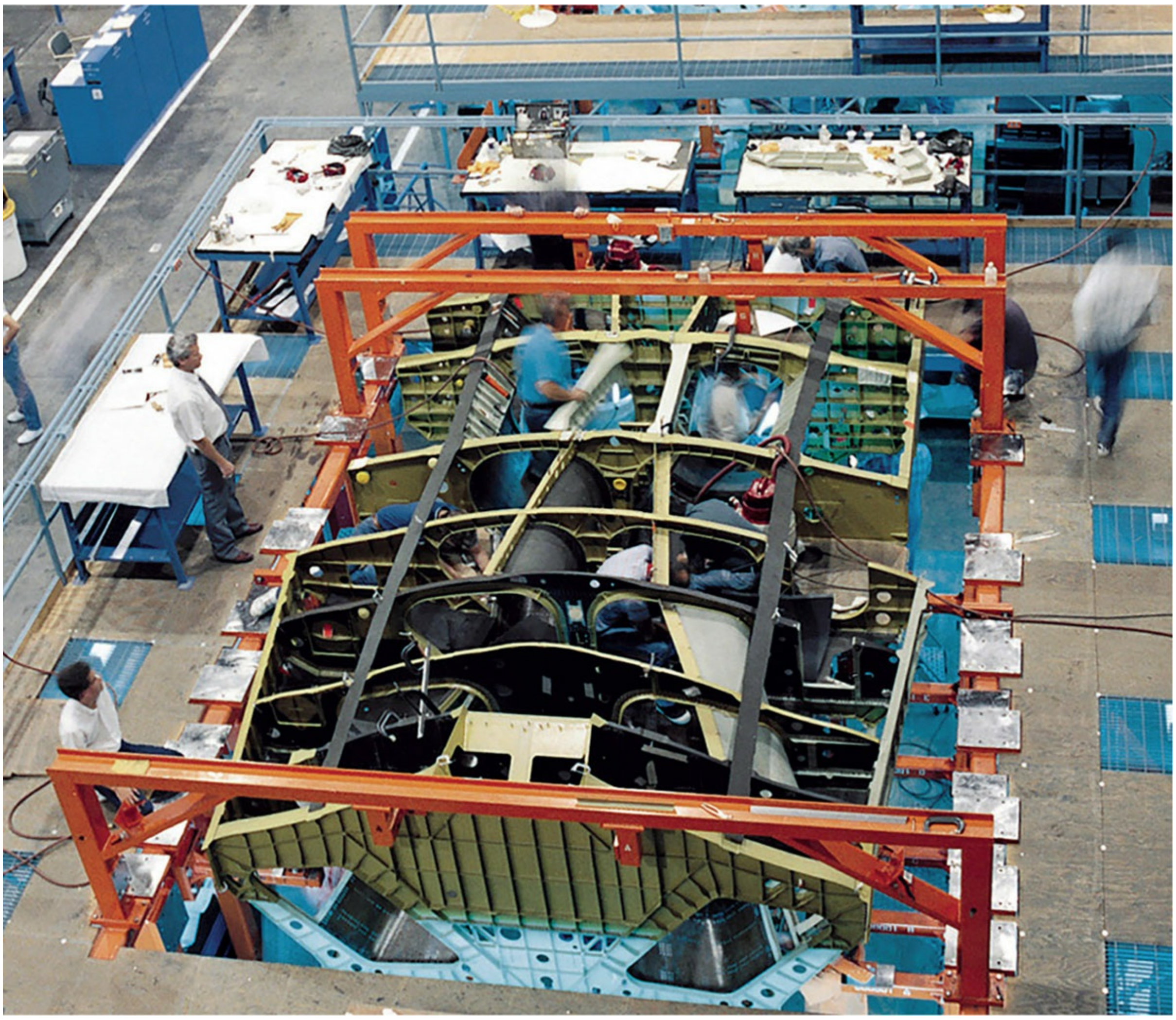
On 25 April 1992, YF-22, PAV-1, aircraft sustained serious damage during a landing attempt as a result of pilot-induced oscillations. It was repaired but never flew again, and instead served as a static test vehicle thereafter. In 1991, it was anticipated that more than 650 production F-22s would be procured, but due to Congress micromanaging the program, production was limited to 195 (eight test and 187 operational aircraft).

On 31 March 1998, the first YF-22 prototype was enshrined in the Air Force Museum. (NMUSAF)

Construction of major wing sections for two prototypes takes place at Boeing in

Seattle, WA; General Dynamics in Fort Worth, TX; and Lockheed in Palmdale, CA. (Lockheed Martin)

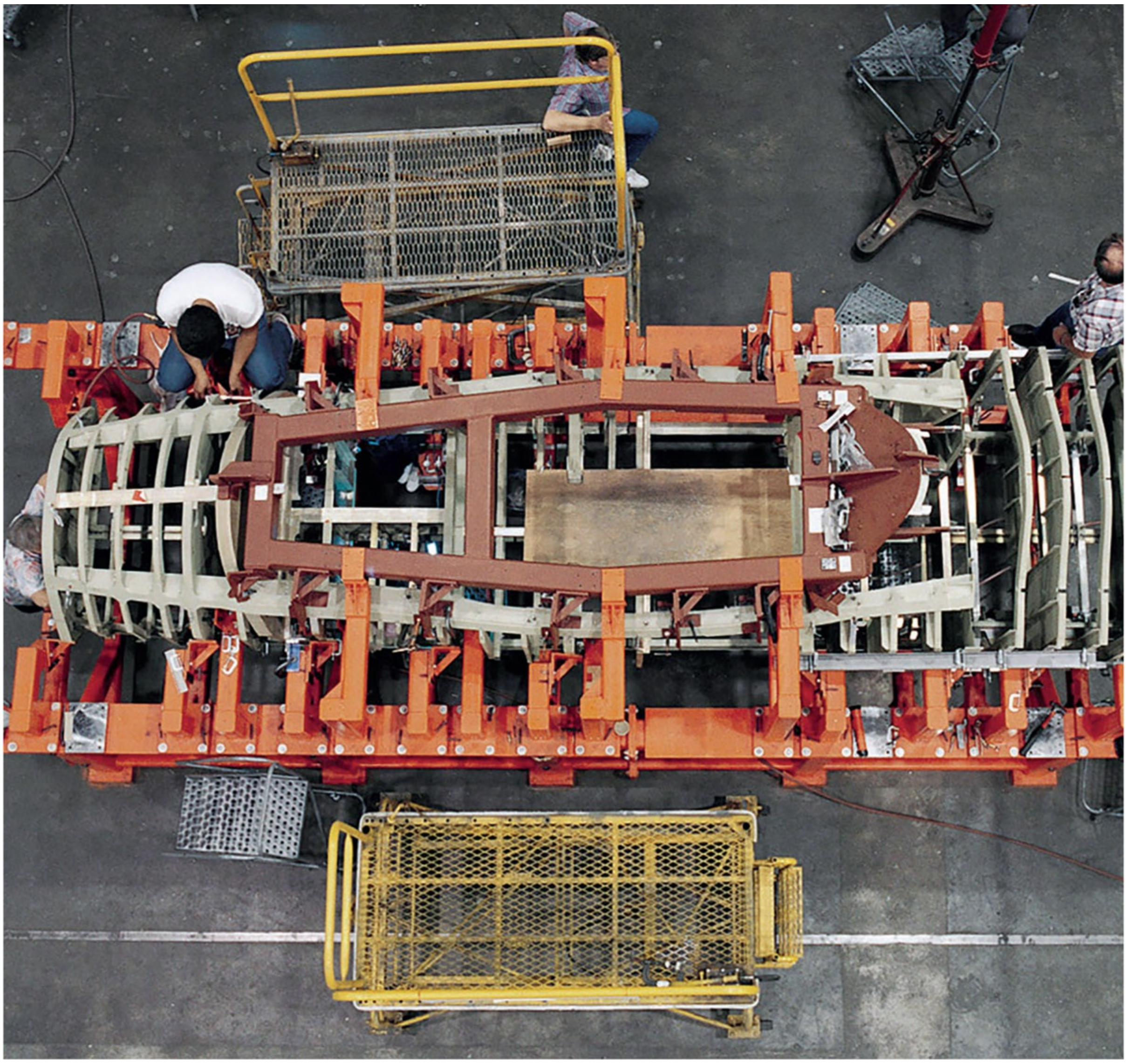
The YF-22 when it was on exhibit at the National Museum of the Air Force, Wright-Patterson AFB, taken on 3 March 2003. (James C. Goodall)



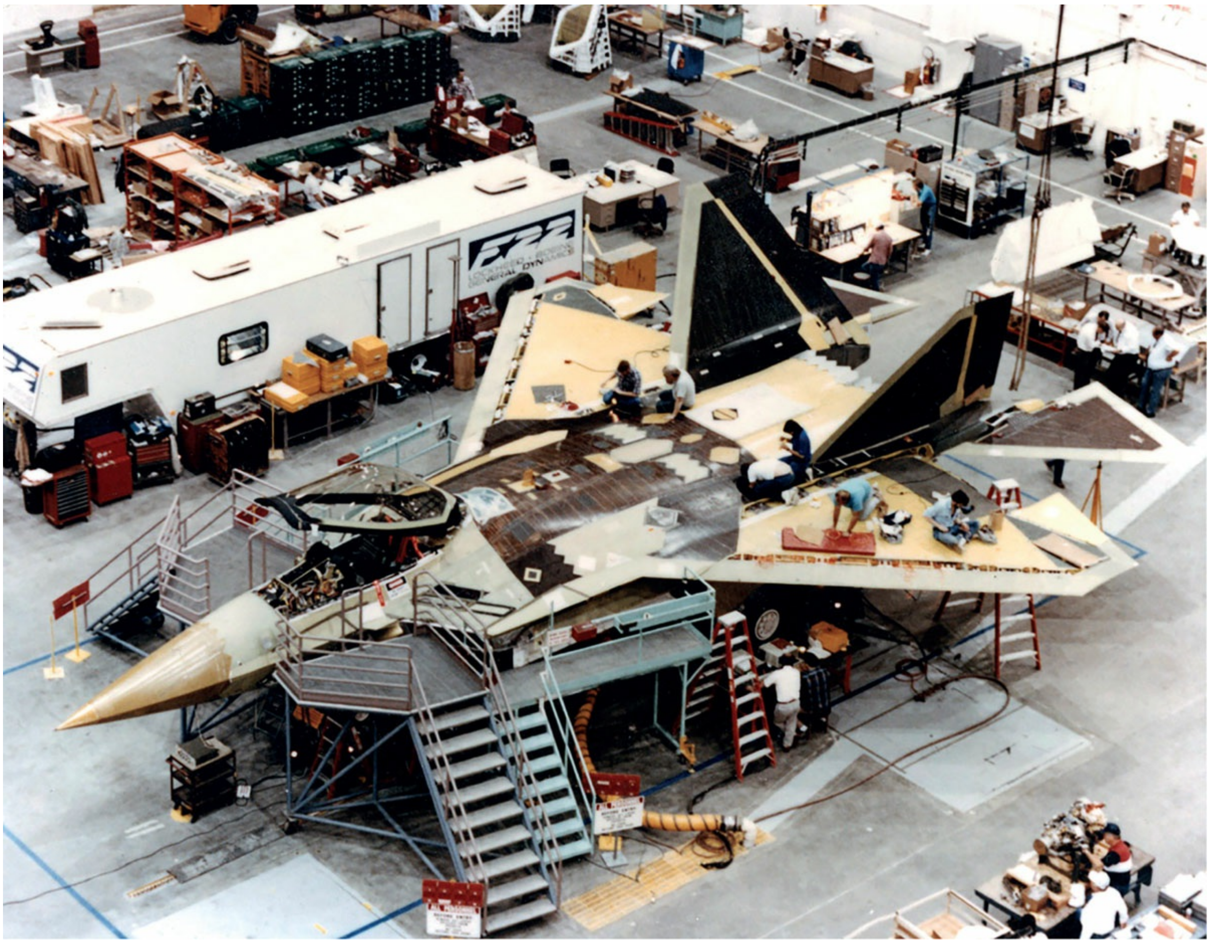
Production buildup being done on the aft fuselage section for the YF-22 at the Lockheed Martin Skunk Works. (Lockheed Martin)

ZERO F.O.D.
NO SMOKING
ATF
YF-22A
AIRCRAFT #1
S/S 3997

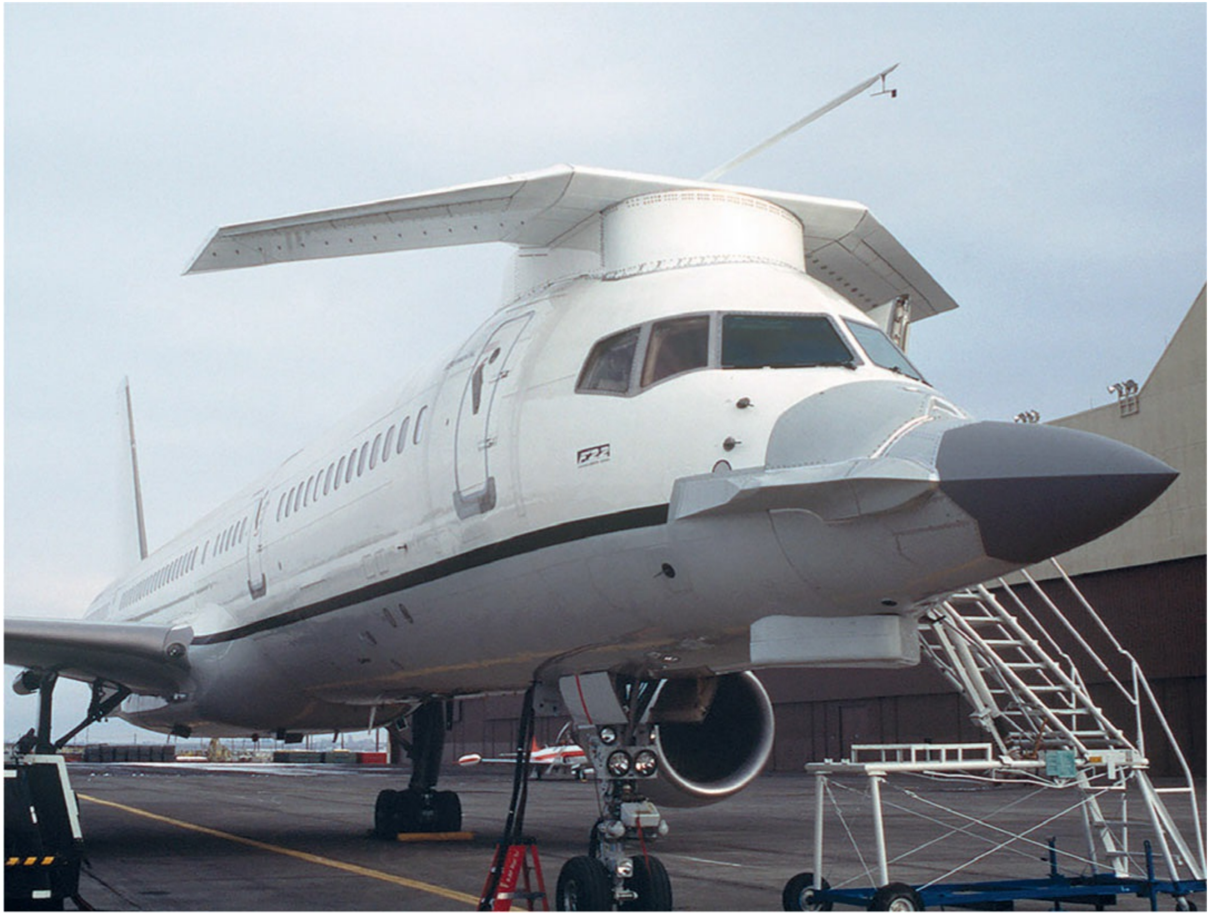
Final assembly of the first YF-22 prototype begins in Palmdale on 13 January 1990. (Lockheed Martin)



The forward fuselage and cockpit assembly in the production fixture at the Skunk Works located at Site 10 at Air Force Plant 42, Palmdale. The forward fuselage was shipped to Palmdale from Burbank for final assembly. (Lockheed Martin)


F22
LOCKHEED
GENERAL DYNAMICS

The assembly of the prototype YF-22 at the Lockheed Martin Skunk Works in the early part of 1998. (Author's collection)



A highly modified and instrumented Boeing 757 that has been retrofitted to act as an F-22 flying laboratory. (Author's collection)

Both YF-22s are photographed on the ramp of the AFFTC at Edwards AFB in early 1991. (Lockheed Martin)

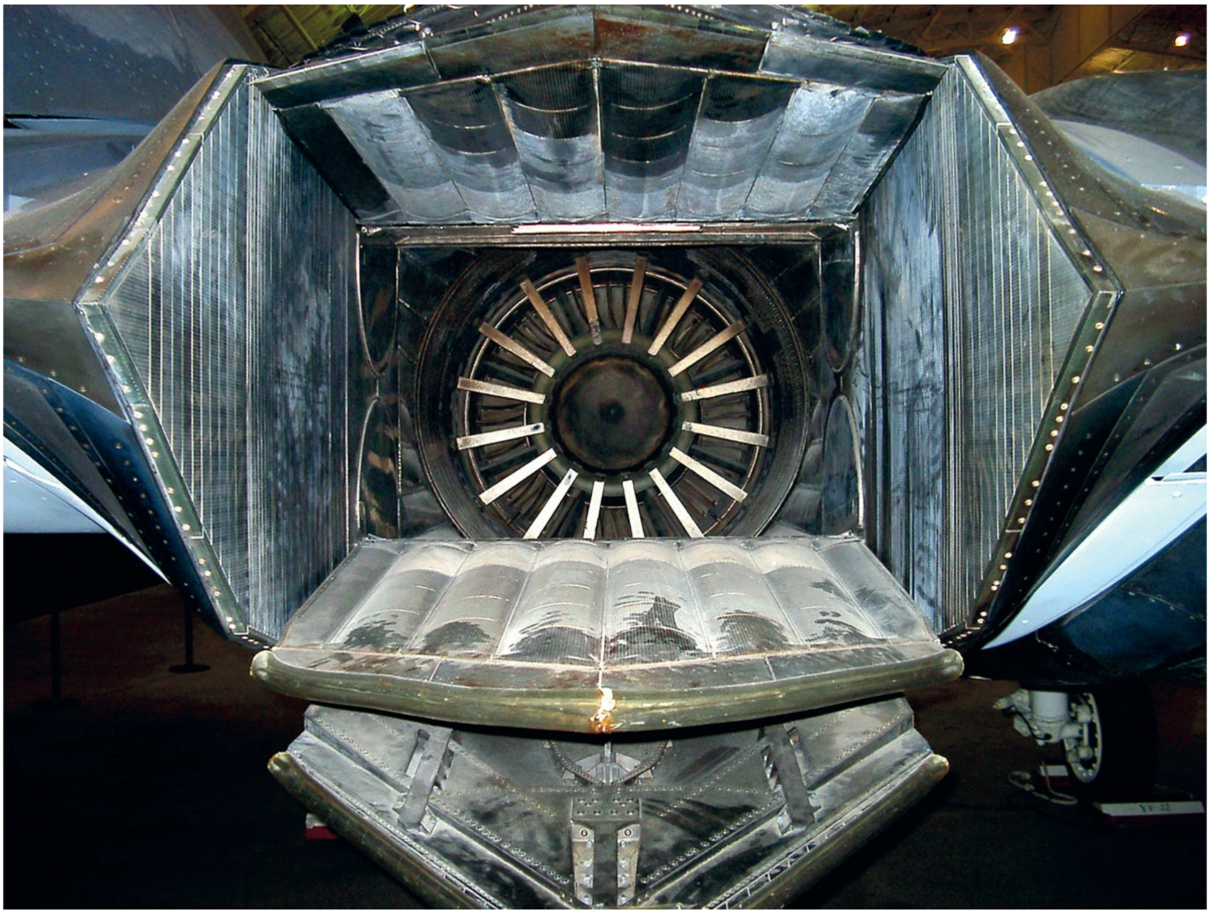
On 30 October 1990, Lockheed test pilot Tom Morgenfeld completes the first flight of the number two YF-22 prototype in a flight from Palmdale to Edwards. This aircraft, called PAV-2, is powered by two Pratt & Whitney YF119-PW-100 turbofan engines. (USAF)

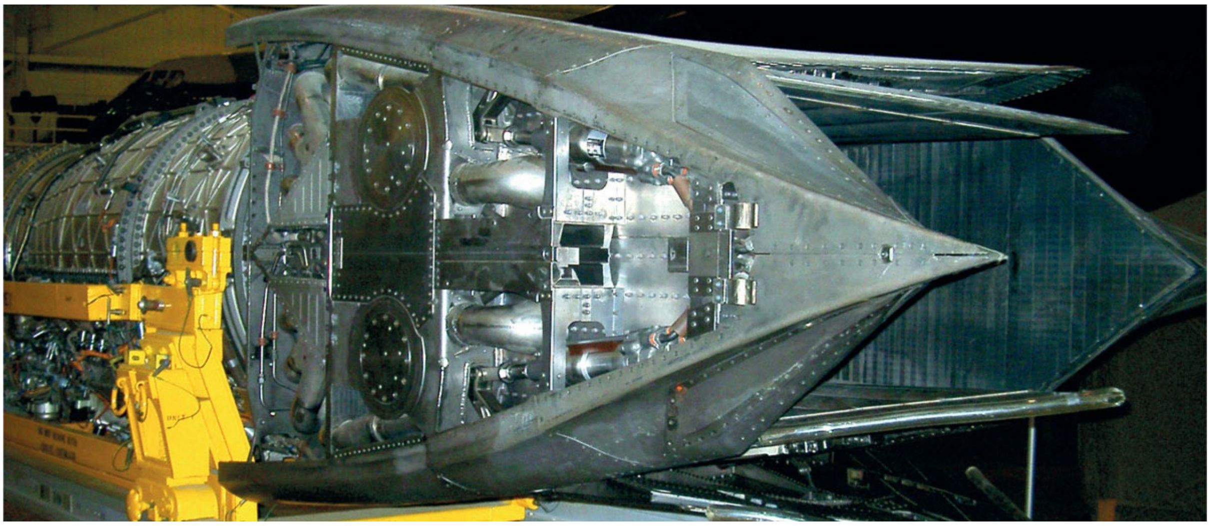
The first aerial refueling of the YF-22 took place on 26 October 1990. Fuel was supplied from a KC-135R tanker assigned to Fairchild AFB, WA. (Lockheed Martin)

YF-22
N22YC
YF-22
N22YX

On 11 December 1990, both YF-22s are flown in formation for the first time. (Lockheed Martin)

Mid-way through its flight-testing on 30 October 1990, the YF-22 is photographed from the boom operator's location after testing its 20mm cannon, as is evident from the gun powder residue on the gun port. (Lockheed Martin)





In the 1980s Pratt & Whitney, a unit of United Technologies Corporation, developed the YF119 prototype engine to meet USAF and US Navy requirements for the Advanced Tactical Fighter Demonstration/Validation program. In 1990 it flew in both the Lockheed/Boeing/General Dynamics YF-22 and the Northrop/McDonnell Douglas YF-23 prototype aircraft. (James C. Goodall)

AIR FORCE RESERVE
U.S. AIR FORCE

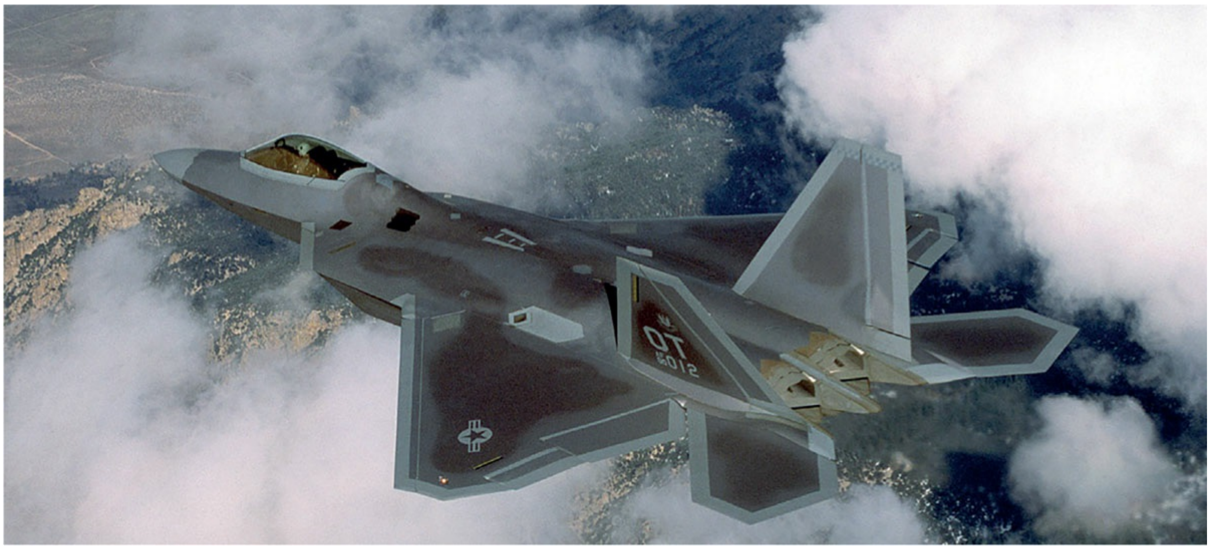
Raptor 01 arrives at the AFFTC at Edwards AFB, on 5 February 1998, aboard a C-5

Galaxy from Westover ARB, MA. The F-22 was partially disassembled for the flight. (USAF)

F/A-22
RAPTOR
4002

On 21 May 2002, the second pre-production F-22 arresting gear system is tested at Edwards AFB. (EAFB/HO)

On 6 February 2004, Boeing pilot Fred Knox flies the first Raptor mission with two 600-gallon external fuel tanks on Raptor 02 at Edwards AFB. (Lockheed Martin)



On 17 January 2003, Lt Col David Rose becomes the first operational Air Force pilot to fly the F-22A. The flight occurs at Nellis AFB. (Lockheed Martin)

An Elmendorf-based F-22A Raptor on final approach is shown without external fuel tanks. (Lockheed Martin)

F-22 Edwards AFB Combined Test Force flying F-22A, 91-4009 during Increment 3.1 Update 4. (Lockheed Martin)

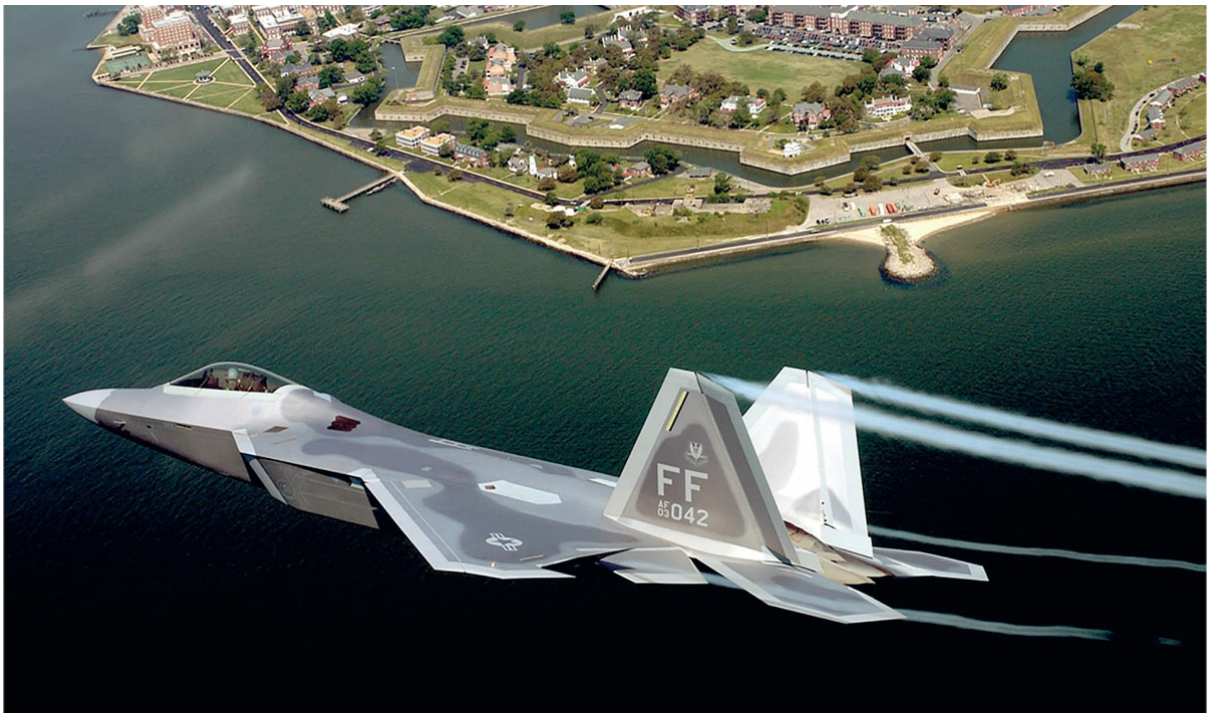
Alaska's strategic location allows the Arctic Raptors to deploy rapidly anywhere in the world. They are nine hours or less flight time to almost any location in the northern hemisphere. (Lockheed Martin)

ED
Raptor 01
001

On 17 May 1998, Raptor 01 is flown for the first time at Edwards AFB. The 1.5-hour flight is the third flight for the aircraft and the first for a USAF pilot, in this case Lt Col

Steve Rainey. (Lockheed Martin)

One of the original F-22 Engineering & Manufacturing Development (EMD) aircraft, 91-007, takes off at Edwards AFB on 20 March 2015. (Author's collection)



An F-22 Raptor flies over the ramparts of Fort Monroe, VA. The 27th Fighter Squadron commander, Lt Col James Hecker, at Langley AFB, flew the first of 26 F-22As. (USAF)

HH
046
HH
048
HH
AF 04 064
HH
HH

One of the few Air Guard units flying the F-22A. The Hawaii Air Guard is based at Pearl Harbor-Hickam, HI. (Author's collection)

FF
AF 04 062
FF
AF 04 063

An F-22A positions into the Langley AFB pattern, on 6 March 2006, to deliver the first F-22A Raptors assigned to the 94th Fighter Squadron. (USAF)

On 7 July 2015, the 94th Fighter Squadron crew chief, checks the F-22A Raptor of Brig Gen Kevin Huyck, 1st Fighter Wing commander, before the start of his final flight at Langley AFB. (USAF)

On its final aproach to Hickam AFB, this Hawaii Air Guard F-22A carries a pair of 600-gallon external fuel tanks. (Author's collection)

LOCKHEED MARTIN
AK
525 FS

In December 2011, the 195th and final F-22 was completed out of eight test EMD and 187 operational aircraft produced; the aircraft was delivered to the USAF on 2 May 2012. (Lockheed Martin)

15 March 2012: The final production F22 Raptor is flown for the first time from the Lockheed Martin facility in Marietta. Company test pilot Bret Luedke put the aircraft through a 1.5-hour initial airworthiness flight, reaching a maximum speed of Mach 1.5. (Lockheed Martin)

LOCKHEED MARTIN
AK
195

On 13 December 2011, the final F-22 Raptor (10-4195) was rolled off the assembly line in ceremonies at Lockheed Martin in Marietta. (Lockheed Martin)

SEA SHADOW IX-529

1985

PROGRAM: IX-529

Name: Sea Shadow

Mission: Stealth surface demonstrator

Length: 164ft (50m)

Beam: 68ft (21m)

Draft: 15ft (4.6m)

Displacement: 563 long tons (572 tons; 0.57 kilotonnes)

Contract Award: 22 October 1982

Out of Service: September 2006

Crew: 4

Number Built: 1

Power Plant: Diesel-Electric

Design Speed: Mach 0.02 (16.3mph; 26km/h)

Combat Radius: N/A (technology demonstrator)

Weapons Load: N/A

It was in the spring of 1978 that the Skunk Works decided to extend their stealth capabilities into the realm of submarines.

The Polaroid concept ... “Time out! There isn’t one thing wrong with your new camera,” said Ben Rich to a company photographer who was complaining that his Polaroid camera was defective after his shots of a model F-117 came out blurry. As it turned out, the stealthy coatings and shaping of the airplane interfered with the camera’s sonar-like device used to focus, making the images appear fuzzy.

When Rich led the Skunk Works, he was always on the prowl to find ideas to expand or exploit the stealth technologies they were developing. After the incident with the Polaroid, Rich realized he could apply the stealth technology of the F-117 to a submarine, making it undetectable on sonar.

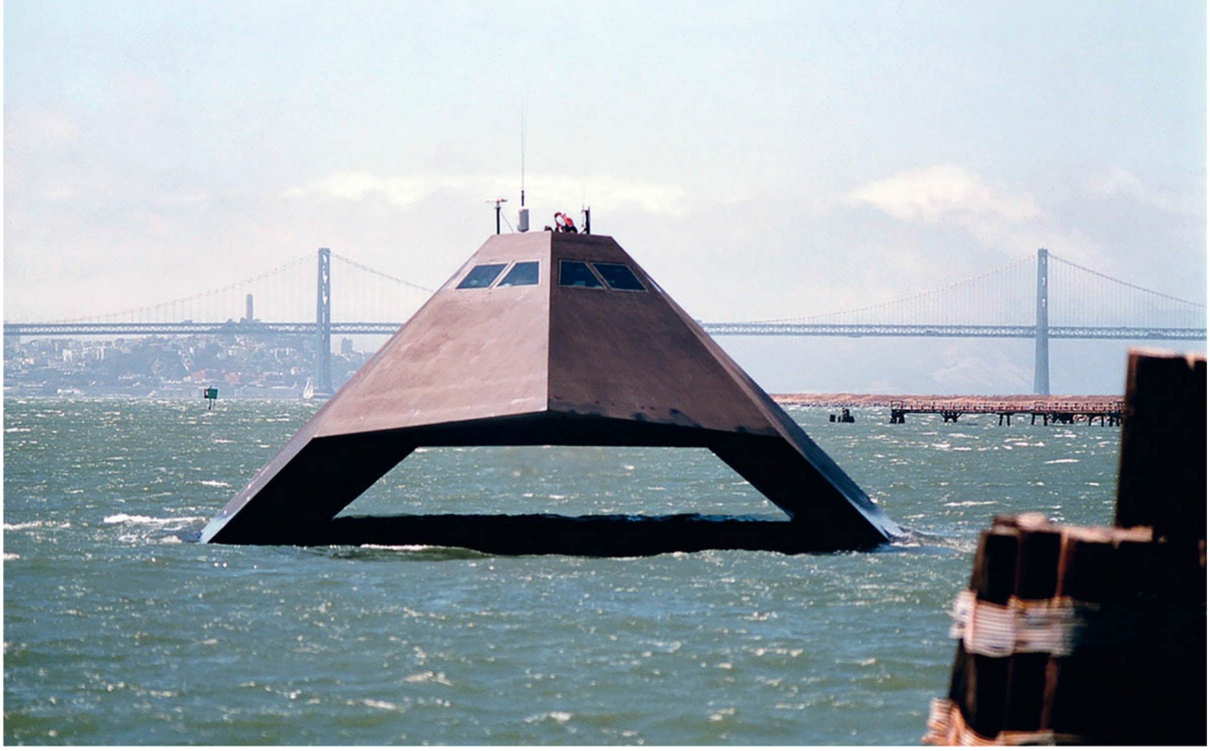
His team got right to work and bought a small model submarine, put faceted fairings on it and tested it in a sonic chamber. Even with such a crude setup, the team members discovered that they had reduced the model’s sonar return by three orders of magnitude. Rich has said that “in the engineering game, improving anything by a single order of magnitude, ten times better, is a very big deal and usually worth a nice bottle of champagne.” Having discovered an improvement 1,000 times better, the Skunk Works decided to pursue designing a stealthy sub.

The initial design consisted of a cigar-shaped hull that was shielded by an outer wall of flat, angular surfaces. These surfaces could bounce sonar signals away and also muffle the engine sounds and the internal noises of crewmen inside the vessel. The Skunk Works team ran numerous acoustical tests in special sound-measuring facilities and obtained dramatic improvements.

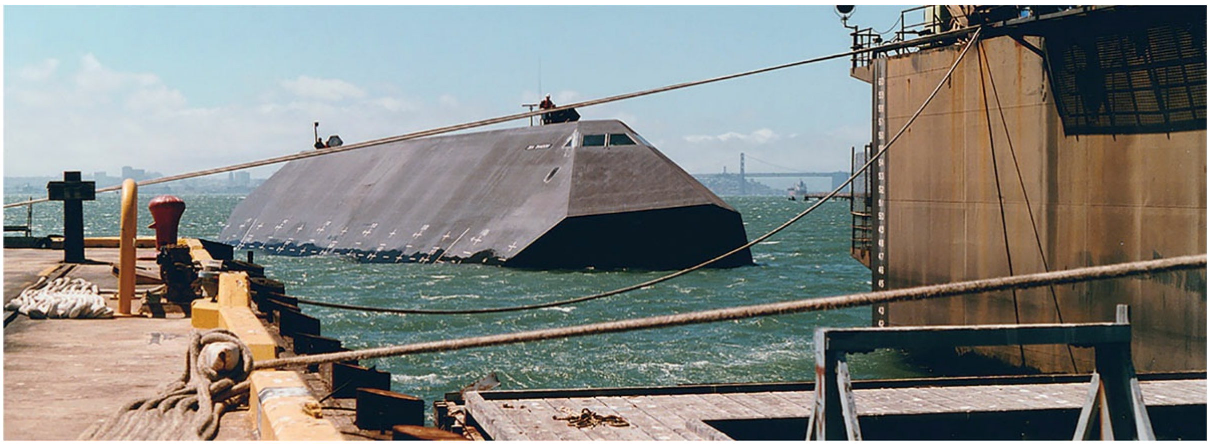
Armed with high hopes, Rich took the design and test results to the Pentagon office of a Navy captain in charge of submarine research and development. To put it lightly, the submarine captain was not convinced the Sea Shadow was right for them. Moreover, he was concerned that the design would cost the Navy two or three knots of speed. Even after rebutting the captain’s complaint by explaining that they would gain invisibility from the enemy, Rich left that trip empty-handed. Just as all hope for this project was lost, a fellow Skunk Works engineer who had just returned from Pearl Harbor informed Rich that he’d seen the Small Water Area Twin Hull (SWATH), a prototype catamaran-style Naval ship. As this had proven to be quicker than a conventional ship and amazingly stable in heavy seas, Rich decided that the SWATH was the perfect model for a stealthy ship. With this news, Rich travelled back to Washington to meet with Defense Undersecretary Bill Perry in a discussion originally planned for the F-117. Dr Perry was intrigued with Rich's idea for a model stealth ship and authorized a contract through DARPA for the Skunk Works to test the effects of stealth shaping and coatings on surface vessels and effects of seawater on radar-absorbing iron ferrite coatings.

At the time, one of the biggest threats against US surface vessels was the Soviet RORS satellite, which used X-band radar. Knowing that shape was the key to defeating such radar, Rich and his team designed the ship using severe flat planes of 45 degree angles that bore a strong resemblance to the Nighthawk. The engineer team, led by Ugo Cody, tested the concept by taking the ship to an ancient lakebed deep within Death Valley, California. There, it filled a 100 x 80ft plastic swimming pool and rigged a radar system that duplicated the Soviet radar satellite. Testing proved successful, resulting in additional funding by the Navy to create the prototype of the Sea Shadow. However, the Ocean division of Lockheed caught wind of the project and managed to convince Rich to pass the project to them, as they were in dire need of new work at the time. Part of this agreement allowed chief engineer Ugo Cody to continue with the program to ensure that the ship builders didn't compromise stealth for performance.

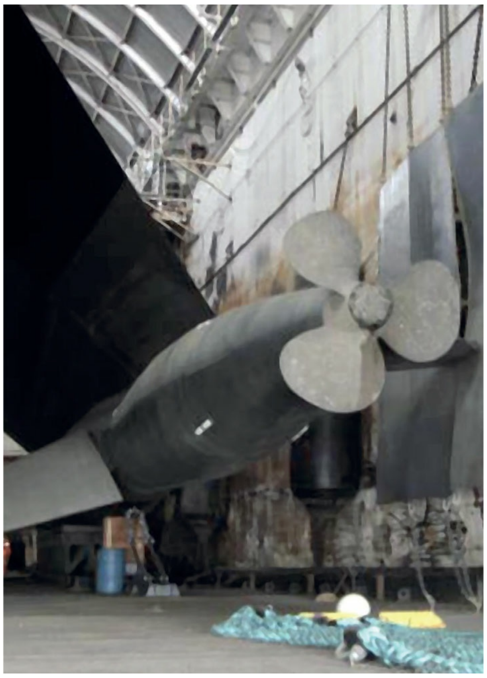
During its first sea trials in 1984, the crew suffered unexpectedly large wakes that were easy to spot on radar and from the air, which was baffling. Not long after, the crewmembers discovered that the motor propellers were installed backward. They quickly corrected the problem and continued to make progress, proving the ship's capabilities. Nevertheless the Sea Shadow was dry-docked before it ever launched beyond testing. However, its technologies were eventually applied to the lower cross section of submarine periscopes and the radar cross section of the Navy's new class of destroyers.



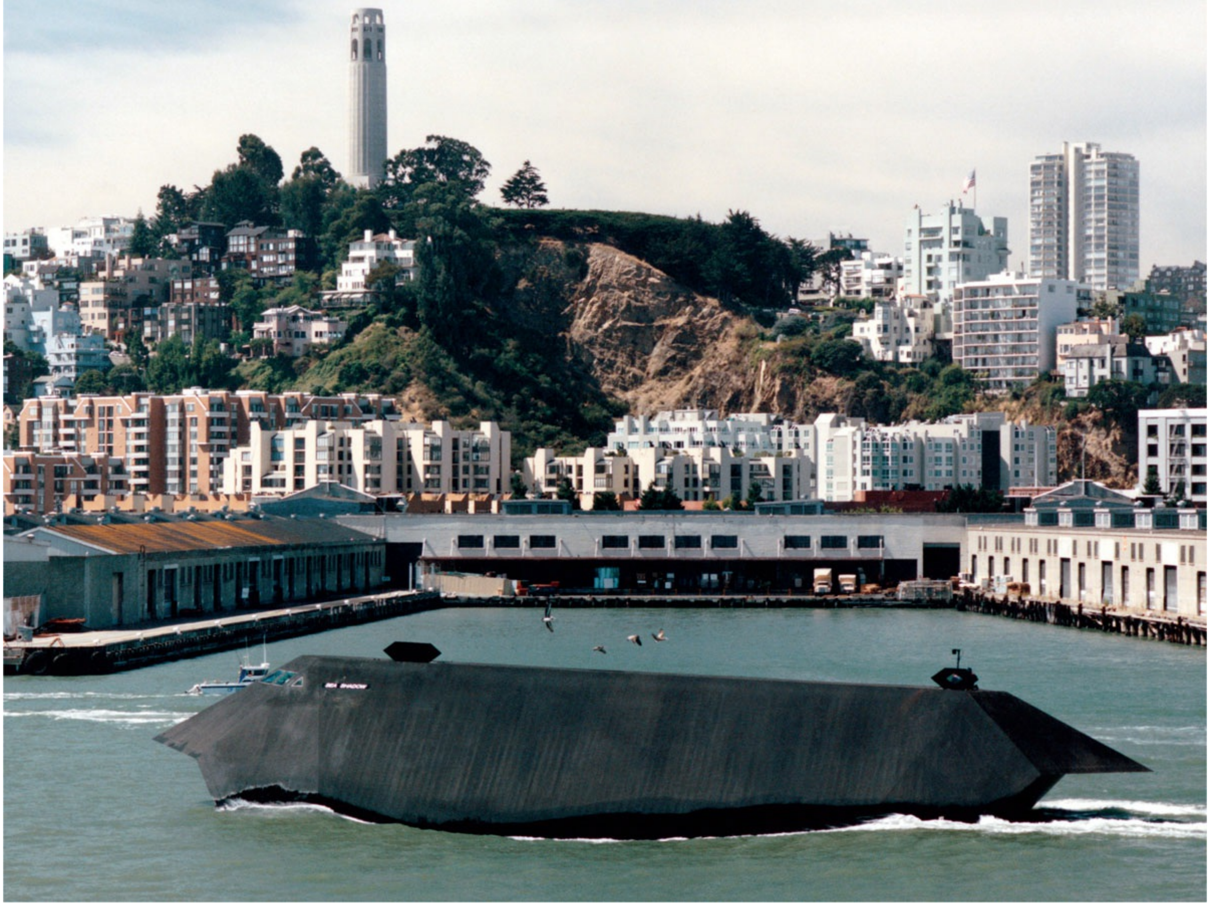
A nose-on view of Sea Shadow as it exited the floating dry dock at the now-closed Alameda Naval Station near Oakland, CA. (James C. Goodall)



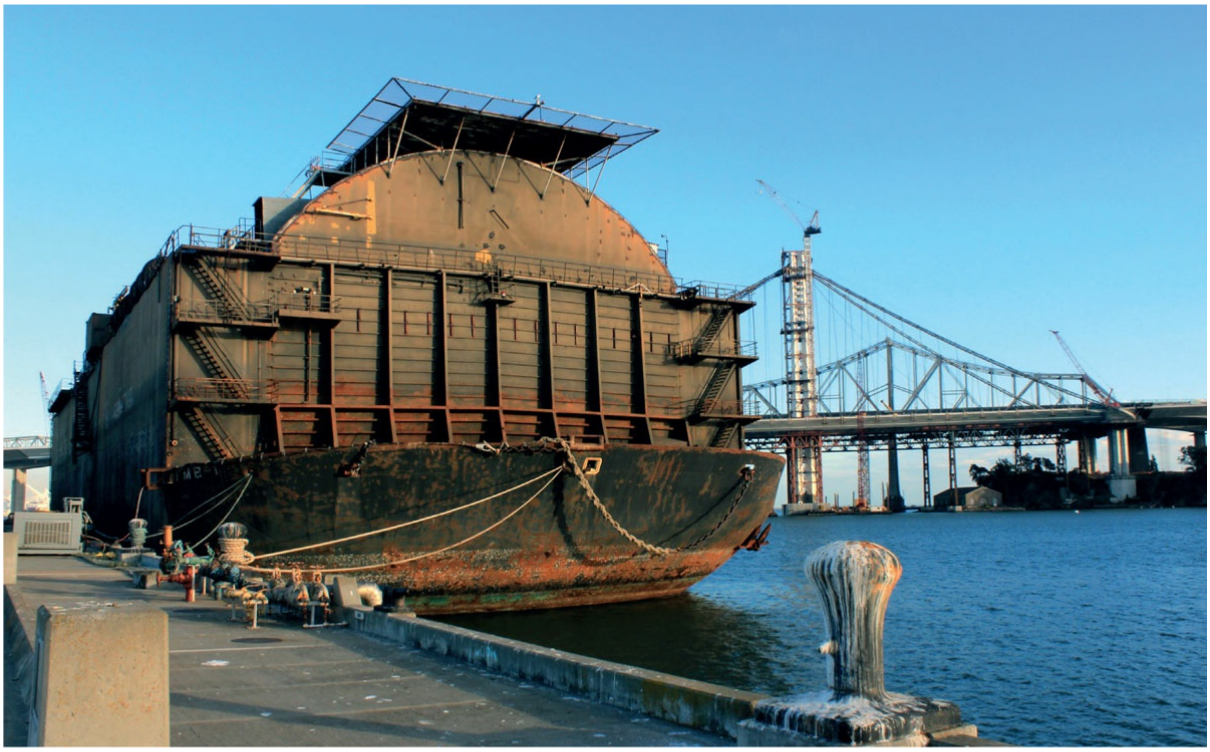
The Sea Shadow, photographed as it exits the Hughes Mining Barge moored at the pier at Alameda NS. The Sea Shadow was developed under a combined Navy and Lockheed Missiles & Space Company program. Its purpose was to explore a variety of new technologies for surface ships. (James C. Goodall)



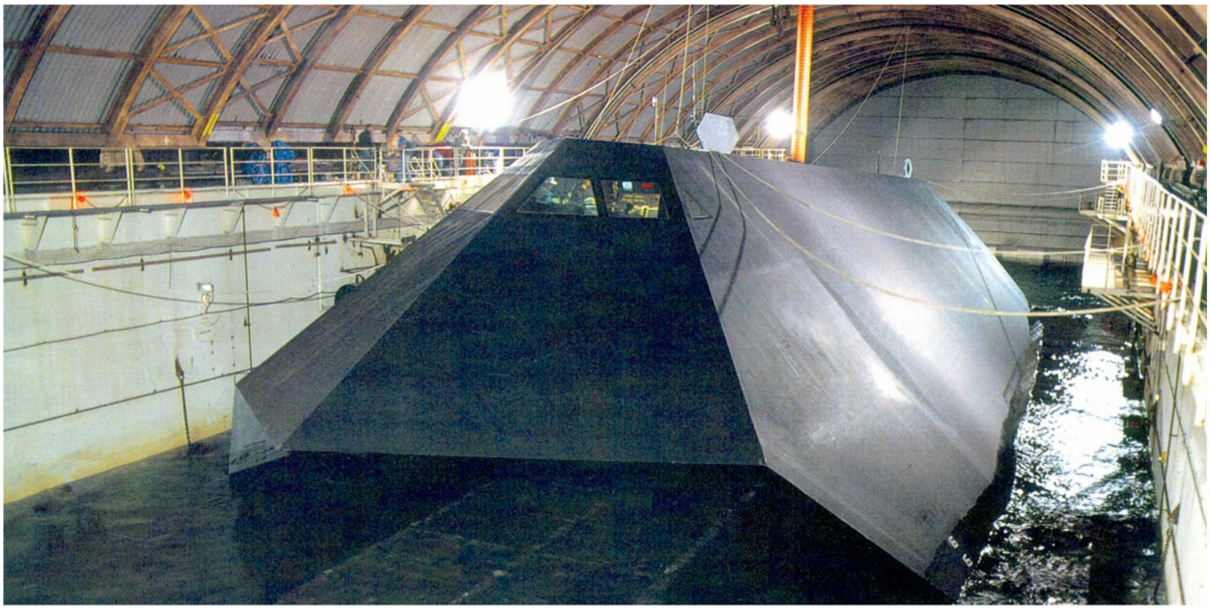
The Sea Shadow, IX-529, was an experimental stealth ship built in Redwood City by Lockheed in 1985 (and made public in 1993) to test the stealth technology of Navy vessels. The ship has two twin hulls, each with propeller and stabilizer. (US Navy)



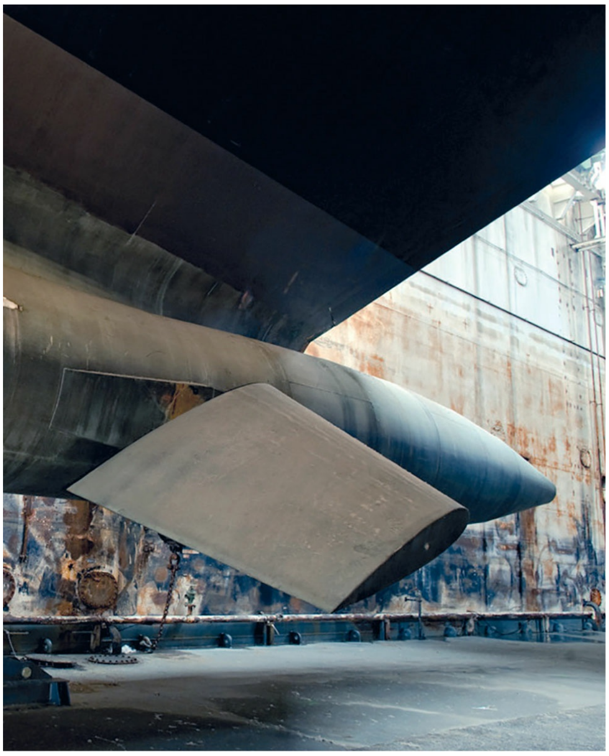
In the 1980s, DARPA, the US Navy and Lockheed Martin outfitted a twin-hull surface ship with the latest in marine and stealth technology. Viewed here is the Sea Shadow passing in front of Coit Tower in San Francisco Bay. (Lockheed Martin)



The protective floating drydock, the Hughes Mining Barge or HMB-1, moored at the Maire Island Naval Ship Yard (now closed) located on Carquinez Strait, the confluence of the Sacramento and San Joaquin Rivers and Suisun Bay. The military built the submersible barge for a secret mission. It carried a tool called "the Claw," which the CIA used to grab a Russian submarine off the ocean floor. (James C. Goodall)

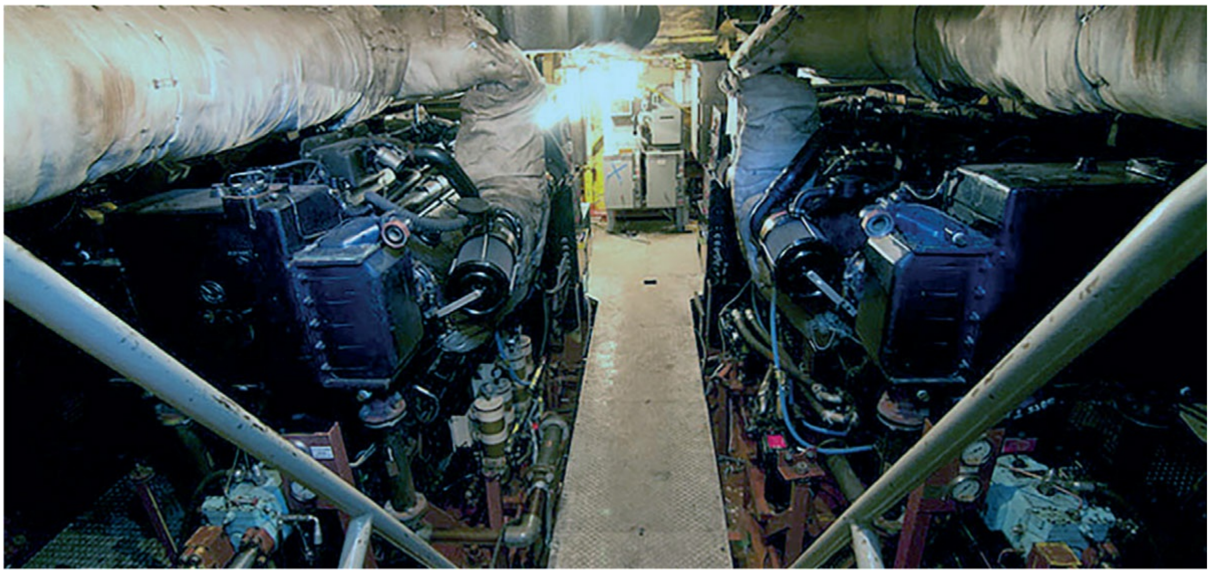


The Sea Shadow was developed to evaluate new technologies to include ship control, structures and automation for reduced manning, sea-keeping and signature control. The program was initiated in the mid-1980s. (Lockheed Martin)

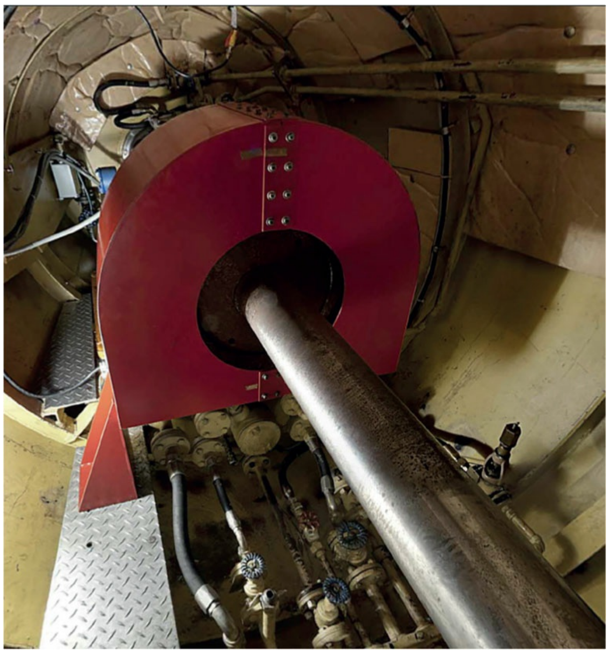


The bow planes on the twin submerged propulsion sponsons. The bow and stern hydrofoils maintain the depth of the hull depending on the sea state. Each of the two hulls of IX-529 had a propeller, a stabilizer and hydrofoils (an arrangement that lifts the hull up to reduce friction when a boat moves at a fast speed). (Author's collection)

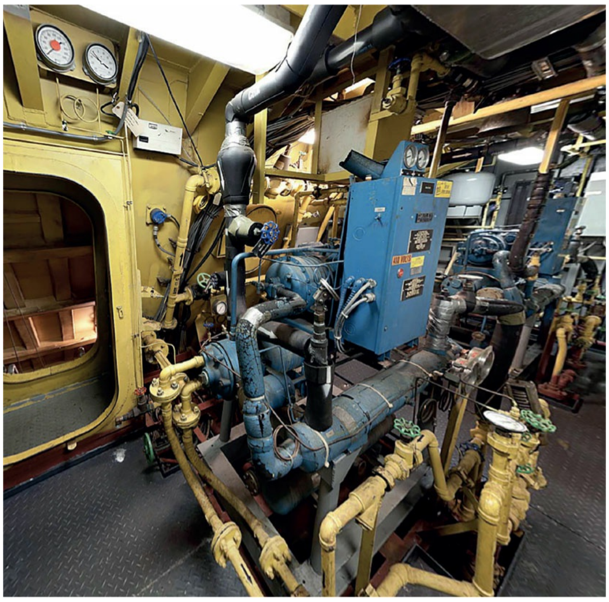
In order for the Sea Shadow to maintain its low-observable signature, a proper ballast has to be maintained. (Author's collection)



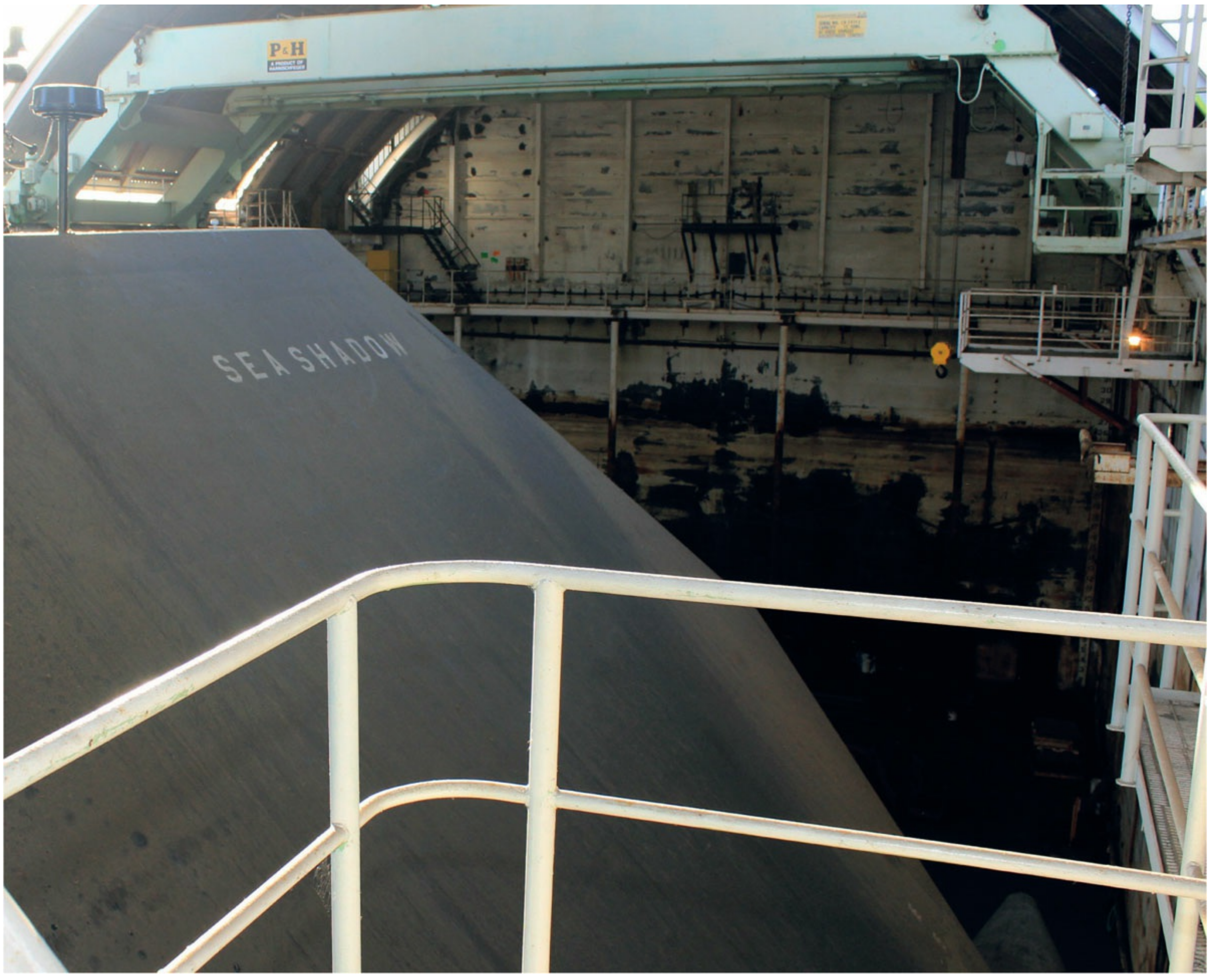
The vehicle is 164ft long, 68ft wide, displaces 560 tons and has a draft of 15ft. It has a maximum speed of approximately 14.2kt and is powered by a twin-screw Stewart and Stevenson diesel electric generators drive. (Author's collection)



The two motor rooms are located in the aft section of the submerged stabilizer/propulsion motor room. (Author's collection)



"Auxiliary Machinery Room 1" contains chillers that create cold water to be circulated in heat exchangers. This is needed to remove heat from tiny underwater hulls that have poor natural circulation through the access trunk, but have a lot of heat-generating equipment such as motors and reduction gear. (Author's collection)



Sea Shadow was revealed to the public in 1993, and was housed at the San Diego Naval Station, CA, until September 2006. (Author's collection)

X-35 JST

1989

PROGRAM: X-35 (not the F-35A/B/C)

Name: Joint Strike Fighter

Mission: Fifth generation fighter

Length: X-35A/B: 50ft 6in (15.39m); F-35C: 50ft 8in (15.44m)

Wing Span: X-35A/B: 32ft 9in (9.98m); X-35C: 43ft (13.1m)

Height: 13ft 4in (4.06m)

Max T.O. Weight: F-35A: 70,000lb (31,751kg)

First Flight: 24 October 2000

Last Flight: 6 August 2001

Crew: 1

Number Built: 2 (The X-35A was converted to the X-35B)

Power Plant: 1 x Pratt & Whitney F119-PW-611

Design Speed: Mach 1.5 (1,150mph; 1,851km/h)

Service Ceiling: 50,000ft (15,000m)

Combat Radius: 771.1 miles (670nm; 1,241km)

Weapons Load: F-35A: 18,000lb (8,100kg)

The Joint Strike Fighter (JSF) program was the result of the merger of the Common Affordable Lightweight Fighter (CALF) and Joint Advanced Strike Technology (JAST) projects. The merged project continued under the JAST name until the engineering, manufacturing and development (EMD) phase, during which the project became the Joint Strike Fighter.

The CALF was a DARPA program to develop a Short Takeoff Vertical Landing (STOVL) fighter for the Marine Corps and replacement for the F-16. In 1992, the Marine Corps and Air Force agreed to jointly develop the Common Affordable Lightweight Fighter, also known as the Advanced Short Takeoff and Vertical Landing (ASTOVL) fighter. The CALF project had potential as a complement to the Lockheed Martin F-22 Raptor.

The JAST program office was established on 27 January 1994 to develop a family of weapons, aircraft and sensor technology with the aim of replacing several disparate US and UK aircraft with a single family of aircraft; the majority of those produced would replace F-16s.

In November 1995, the United Kingdom signed a memorandum of understanding to become a formal partner, and agreed to pay $200 million, or 10 percent of the concept demonstration phase.

The evolution of the Joint Strike Fighter (JSF) design from the X-35 demonstrators to the F-35A/B/C configuration has seen significant changes to the aircraft's shaping, critical to its stealth performance. While the design of the inlets was improved, the lower fuselage design is now inferior to the original X-35 configuration. The latter has important implications for the JSF's ability to survive when penetrating modern integrated air defense systems (IADS).

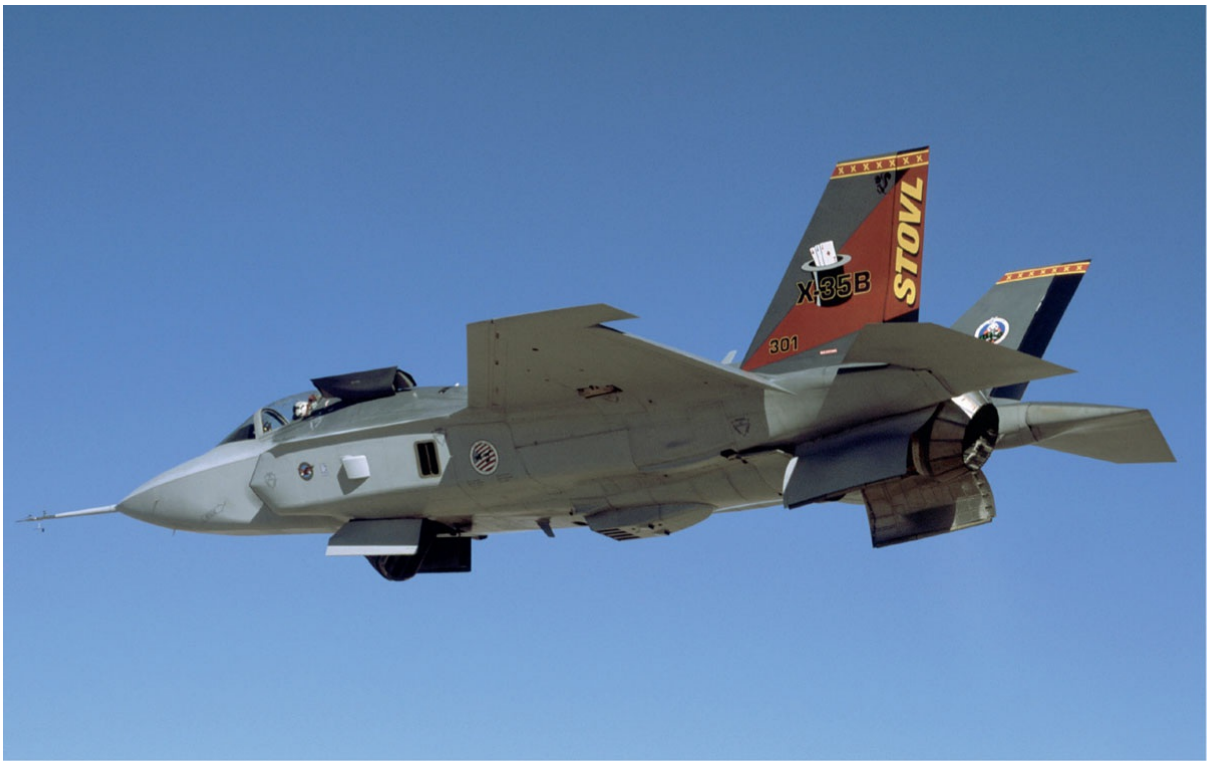
The JSF is demonstrably not a true stealth aircraft in the sense of designs like the F-117A, B-2A and F-22A, as its stealth performance varies much more strongly with aspect and threat radar operating frequency band. Stealth shaping is widely regarded as accounting for the first hundredfold reduction in aircraft radar signature, compared to non-stealthy designs of similar size, with application of glossy and absorbent materials used to further reduce the signature where feasible.

The degradation of the initially intended JSF stealth performance occurred during the System Development and Demonstration (SDD) program when a series of design changes made to the lower fuselage of the aircraft resulted in fundamental shaping changes in comparison with the X-35 Dev/Val prototype aircraft.

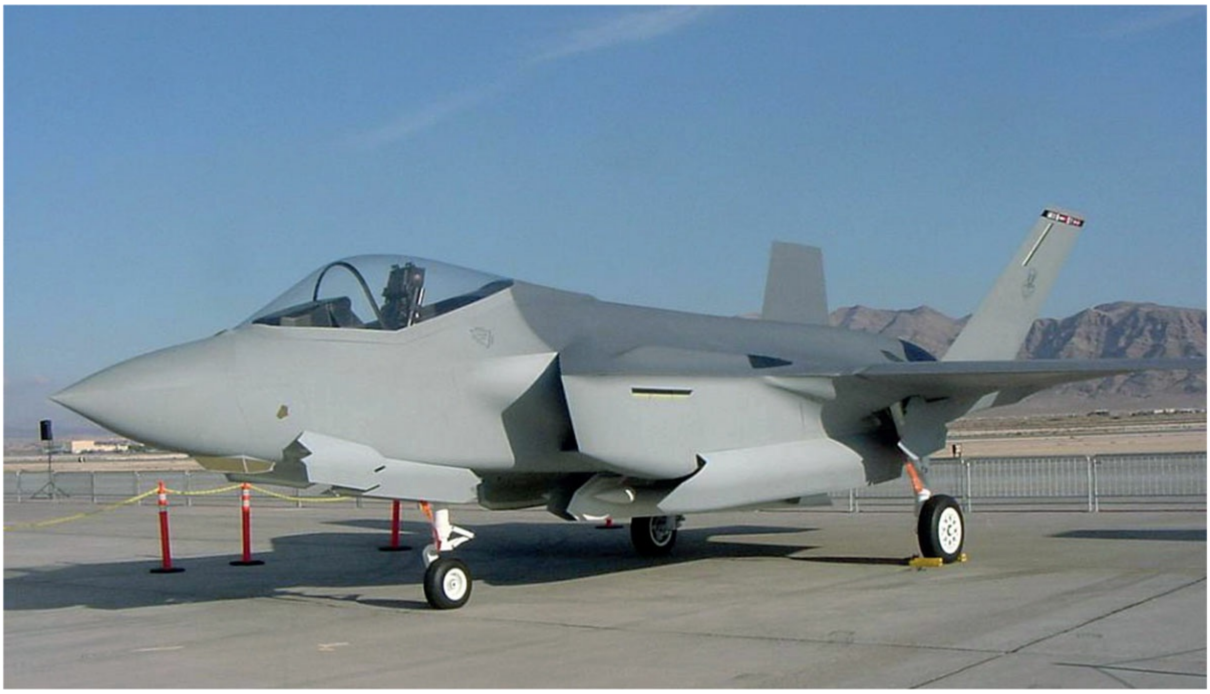
As a result, the tactical options available to JSF users when confronted with penetrating modern IADS are mostly those necessary to ensure the survival of non-stealthy legacy aircraft types. The result of these limitations is that the operational economics of a fighter force using the JSF will be much inferior to a force using a true all-aspect stealth aircraft such as the F-22A Raptor.

Moreover, it is clear that future JSF users will pay a significant price penalty for a stealth capability unable to deliver much, if any, return on such investment. The clean wing fuselage joint and flat low-curvature lower fuselage of the X-35 had the potential to yield quite good beam/side aspect radar signature, but the revised SDD design discarded this arrangement in favor of a much inferior contoured design, clearly intended to accommodate the larger weapon bays. While the F-35 SDD engine inlet arrangement is superior to the X-35 Dev/Val prototype inlet design, the gains in the forward sector cannot overcome the performance losses incurred in the beam/side aspect sectors.

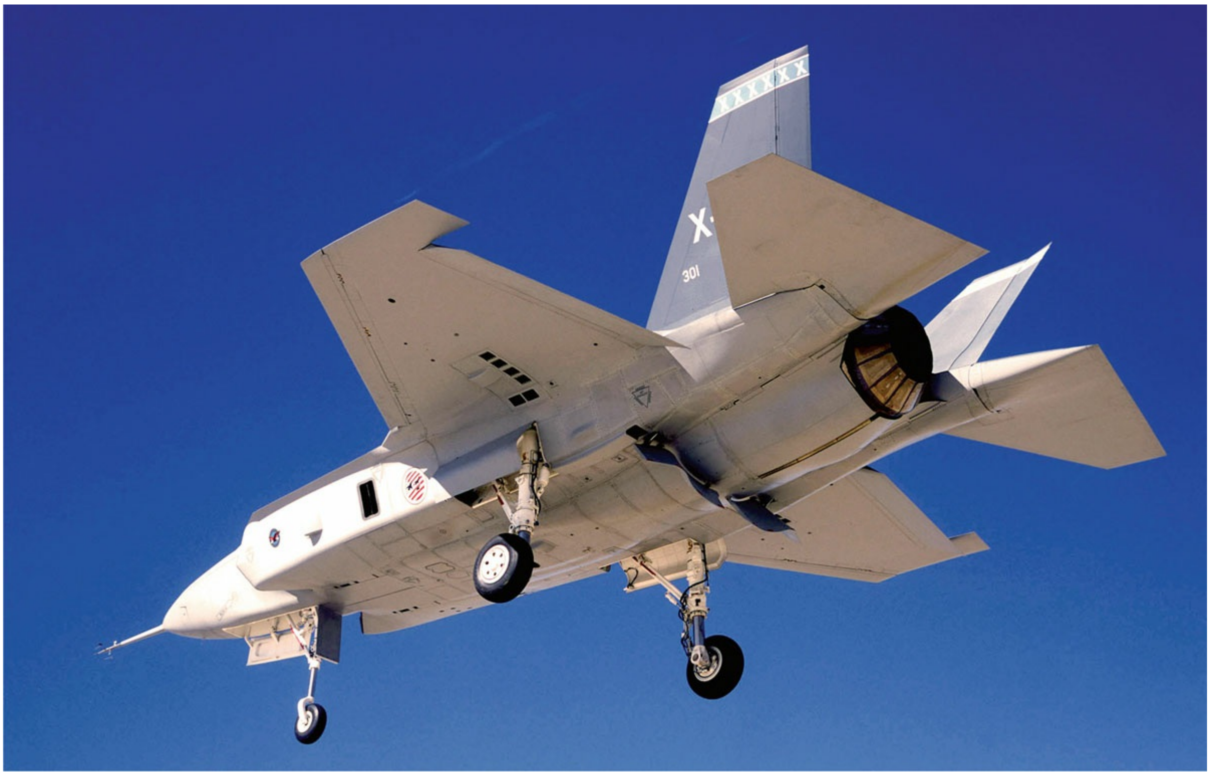
The Joint Strike Fighter (JSF) is being built in three variants: a conventional takeoff and landing aircraft (CTOL) for the USAF; a carrier-based variant (CV) for the US Navy; and a Short Takeoff Vertical Landing (STOVL) aircraft for the US Marine Corps and the Royal Navy. (Lockheed Martin)



The most unusual version of the X-35 family of aircraft is the Short Takeoff Vertical Landing (STOVL); here the STOVL doors are in the open position. (Lockheed Martin)



The full-size mockup of the F-35A is shown on display at Nellis AFB during an open house in the fall of 1999. (Lockheed Martin)



Bottom view of the X-35A, the conventional takeoff and landing variant of the X-35 of the three versions being tested. (Lockheed Martin)

The prototype Lockheed Martin X-35A Joint Strike Fighter receives fuel from a USAF KC-135 Stratotanker during a test mission on 7 November 2000. (USAF)

United Rentals
534D9-45
STOVL

The X-35B STOVL version of the JSF is disassembled and placed on a truck headed to the Smithsonian Institute's National Air and Space Museum in Washington, DC. (Author's collection)

This aircraft was originally the X-35A and was modified to include the lift-fan engine for testing of the STOVL concept. (Lockheed Martin)

A look-down view of the X-35A as it flies over Rogers Dry Lake at the Edwards AFB main base. (USAF)

This 4 December 2002 view of the X-35B STOVL version of the F-35 family as it prepares for its very first vertical hover at the Lockheed Martin site at Air Force Plant 42, Palmdale. (Lockheed Martin)

The X-35A flies over the southern range of Sierra Nevada and the foothills near Death Valley in mid-2000. (USAF)

STOVL
BF-01
F-35

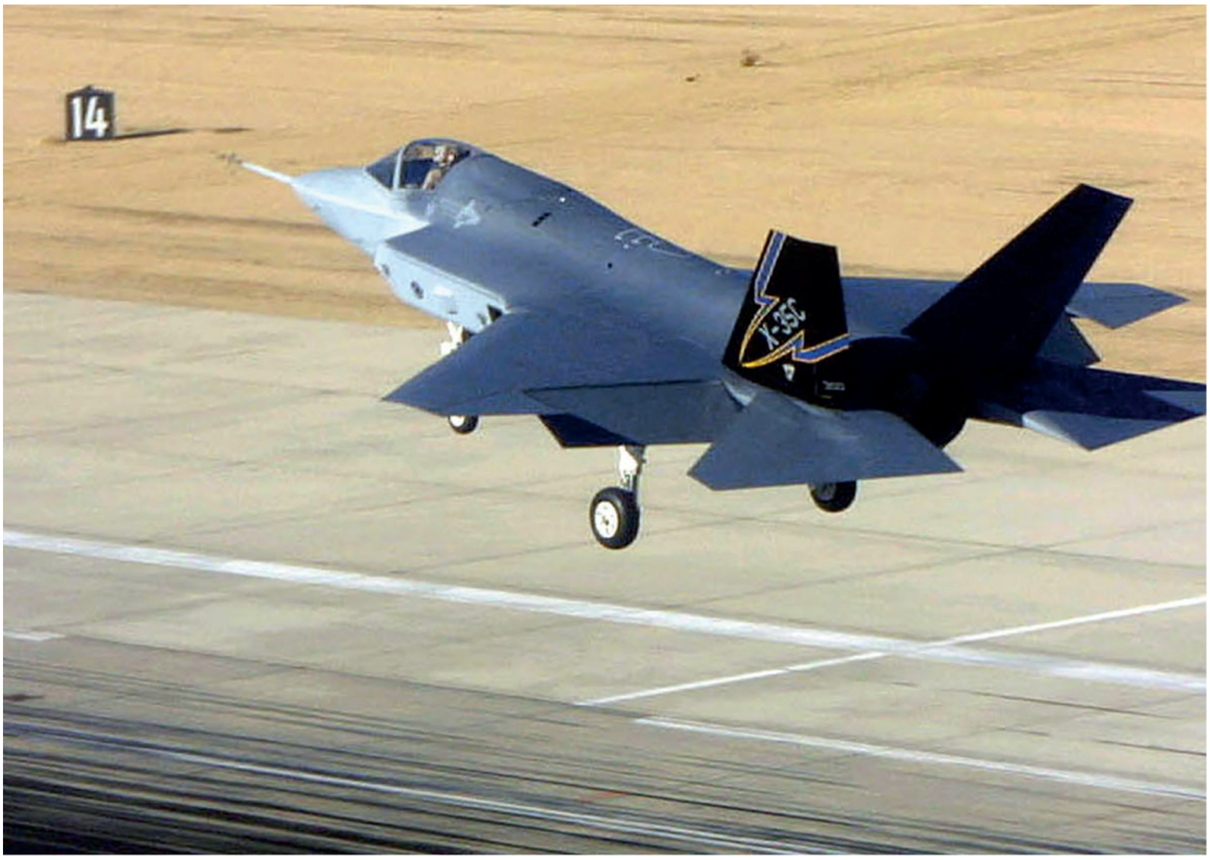
This photo is that of the first full-scale development F-35B during a production test flight at Edwards AFB, CA. The F-35B can land vertically like a helicopter and take off in very short distances. (Lockheed Martin)

The X-35C, the navalized version of the F-35 family is moved in from the weather shortly after it arrive at Patuxent River Naval Base on 10 February 2001. (US Navy)

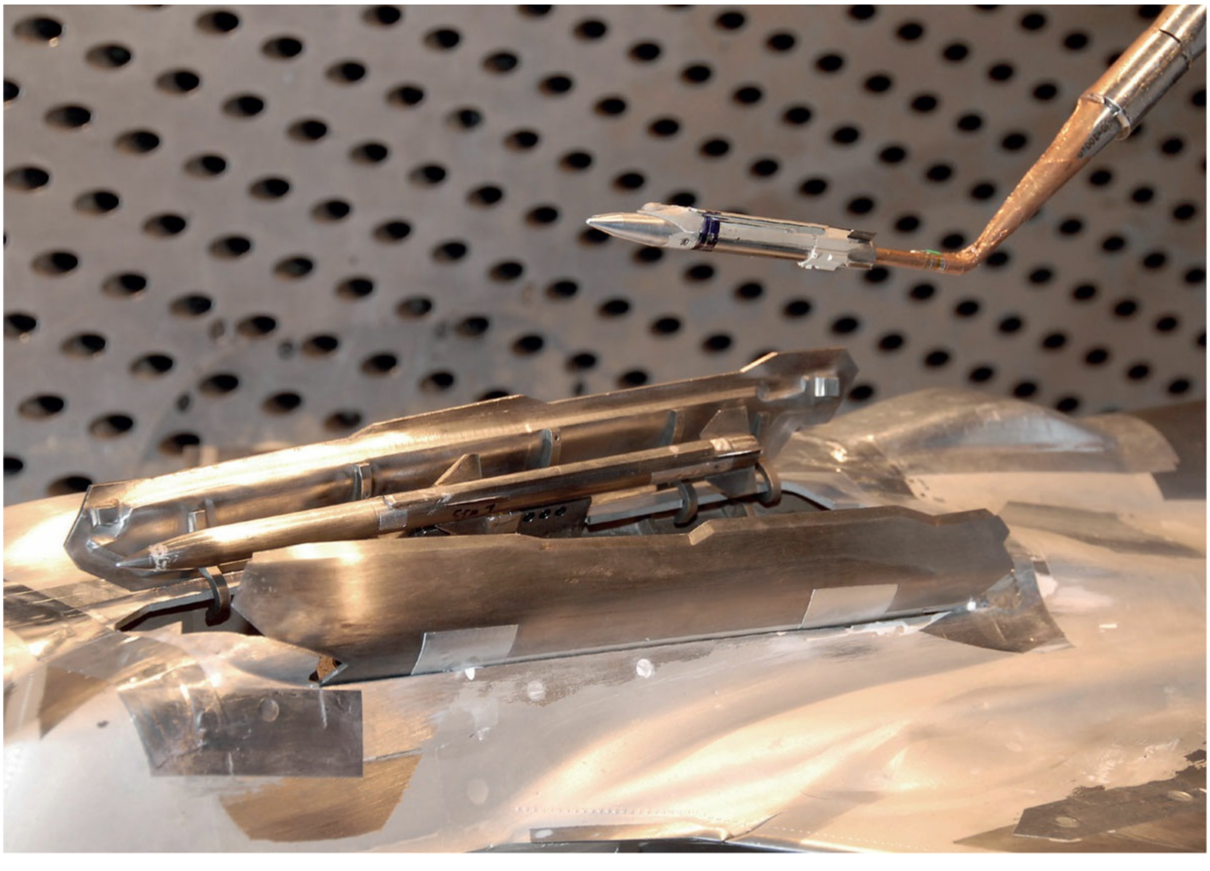
X-35
ED
AF 83 172
AIR FORCE
USAF

A Lockheed Martin X-35 flies in formation with an Edwards AFB Air Force Test Center-based F-16B as it passes over Rogers Dry Lake. (Author's collection)

The X-35C testing nears completion at Edwards AFB. (Lockheed Martin)

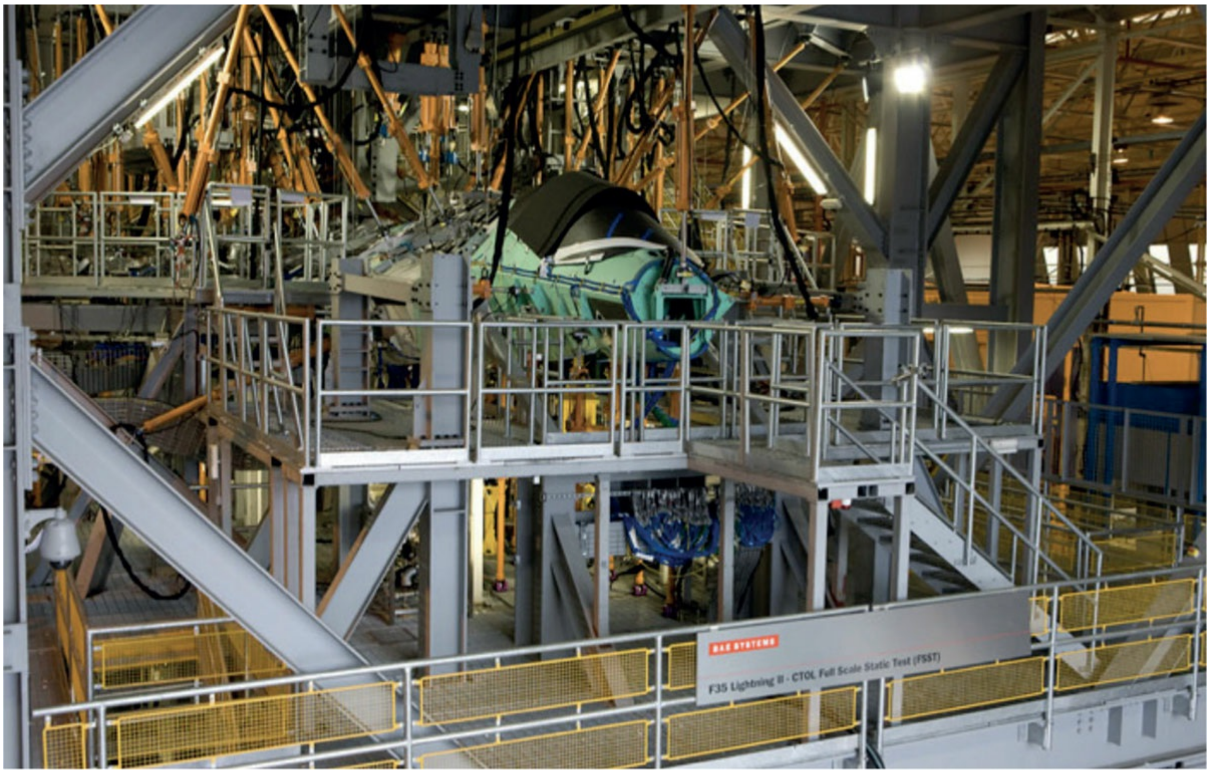


Lockheed Martin's X-35C JSF touches down at Edwards AFB on 18 December 2000 after its first flight. The carrier variant JSF was tested at Edwards and NAS Patuxent River. (Lockheed Martin)



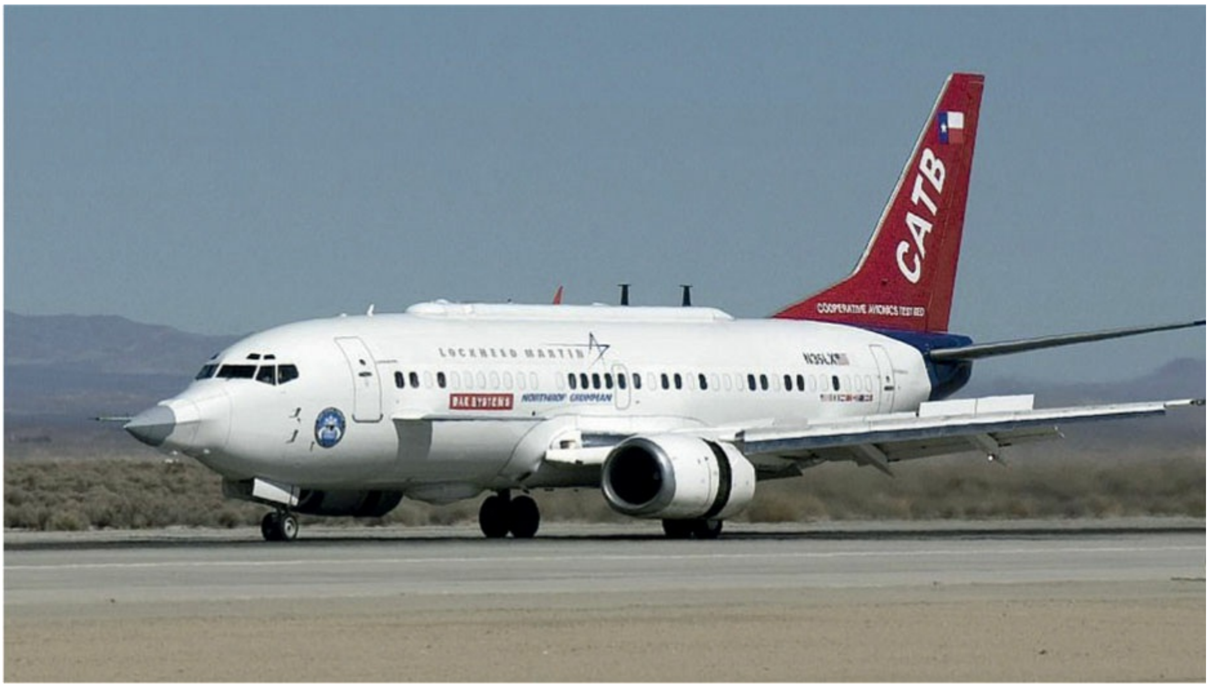
The USAF Arnold Engineering Development Center (AEDC) is the most advanced and largest complex of flight simulation test facilities in the world. AEDC separation testing of the ASRAAM, or AIM-132, was conducted in the 4ft transonic aerodynamic wind tunnel, one of 53 aerodynamic wind tunnels at the AEDC propulsion wind tunnel facility, in 2008. Pictured is a test model of the F-35 with AIM-132 separating from the weapons bay. (AEDC)

Separation testing of the ASRAAM, or AIM-132, was conducted in the 4ft transonic aerodynamic wind tunnel at the AEDC propulsion wind tunnel facility in 2008. Pictured is a test model of the F-35 with AIM-132 separating from the weapons bay. (Lockheed Martin)

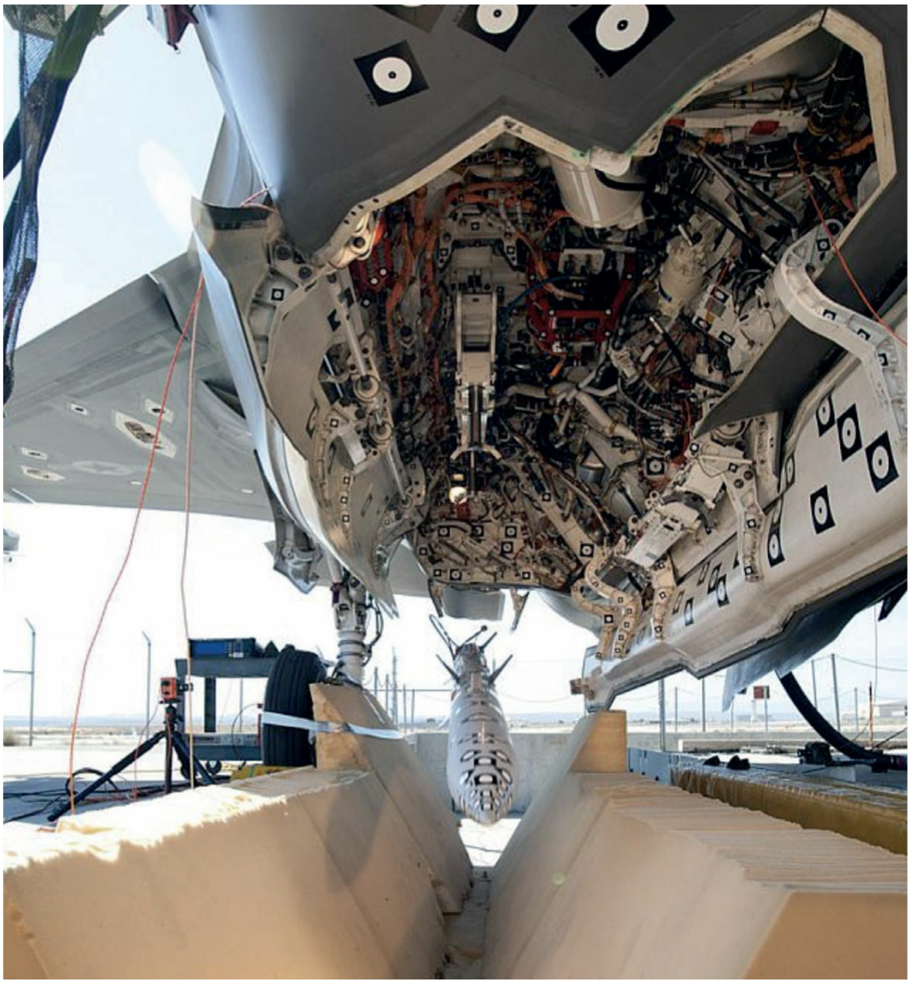

BAE SYSTEMS
F35 Lightning II - CTOL Full Scale Static Test (FSST)

A Lockheed Martin F-35A Lightning II undergoes static testing at BAE Systems' Structural & Dynamic Test Laboratory in Brough, England. The testing was completed five months ahead of schedule and confirmed that the jet's airframe could withstand aerodynamic forces 50 percent beyond design limits. (Lockheed Martin)

A full-scale F-35 JSF model is perched atop a pedestal overlooking a rural valley in central New York. Engineers from the Air Force Research Laboratory's antenna research and measurement facility here are testing the aircraft's sophisticated antenna. (Lockheed Martin)

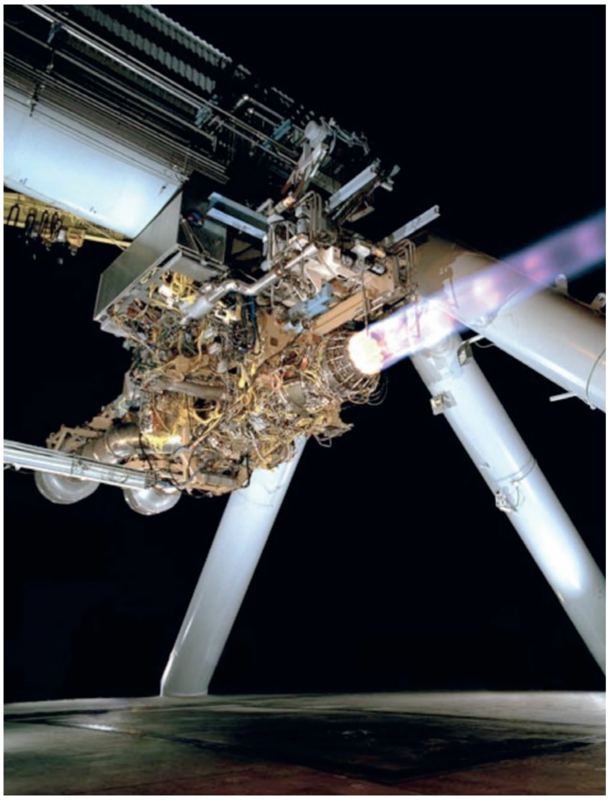

CATB
COOPERATIVE AVIONICS TEST BED
LOCKHEED MARTIN
BAE SYSTEMS
NORTHROP GRUMMAN

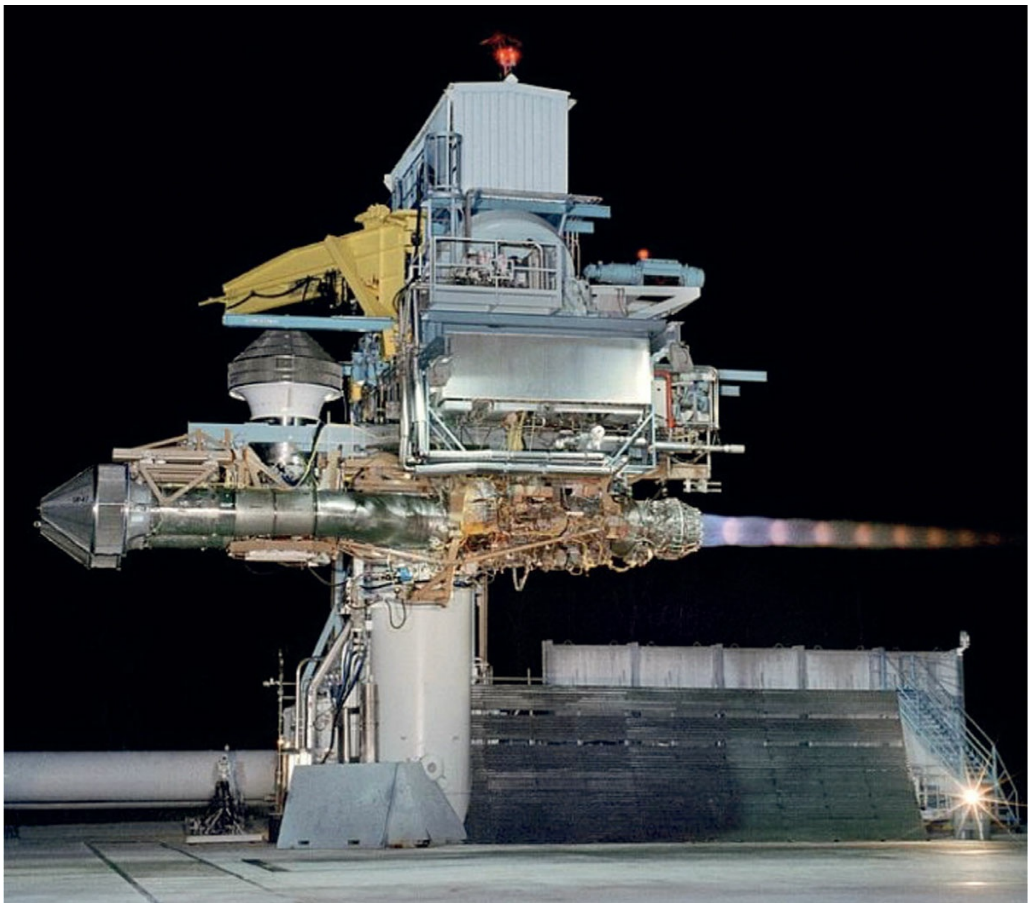
The F-35 Joint Strike Fighter program's Cooperative Avionics Test Bed, or CATB, aircraft lands on 1 March 2007, to perform equipment fit checks. The aircraft is a Boeing 737-300 specially modified to perform mission systems testing for the F-35 program. (Author's collection)



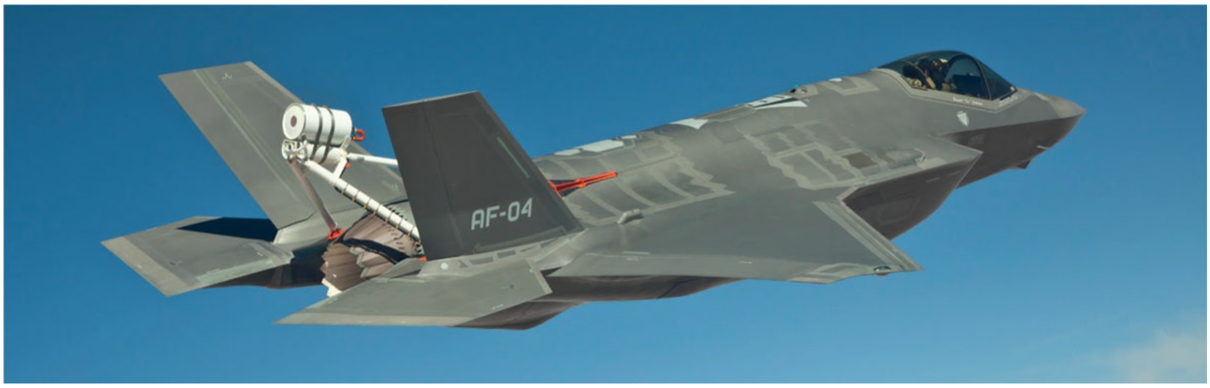
Weapons ejection testing at Edwards AFB to ensure that any internal weapon is put through the steps that it may experience during weapons separation. (Author's collection)

The F-35 alternate engine made by General Electric and Rolls Royce, known as the F136, is shown ready for static testing at General Electric's Evendale, OH, test facility. The F136 was an advanced turbofan engine being developed by General Electric and Rolls Royce plc for the Lockheed Martin F-35 Lightning. (USAF)





The Pratt & Whitney-led F135 propulsion system team is testing its second F135 Short Takeoff and Vertical Landing (STOVL) propulsion system, engine number FX643. The tests on FX643 are focused on endurance testing. (USAF)



The fourth F-35A is shown airborne with the "Spin Chute" recovery fixture installed on its aft fuselage. (USAF)

WA
USAFWS
AF 5051

F-35A 12-5051 of the 16th Weapons Squadron coming in for landing at Nellis AFB. (Author's collection)

Lockheed Martin test pilot Bill Gigliotti flew the ninth production model of the F-35A (AF-14 - serial number 09-5001) on its inaugural flight on 2 March 2012 from NAS Fort Worth, TX. (Lockheed Martin)

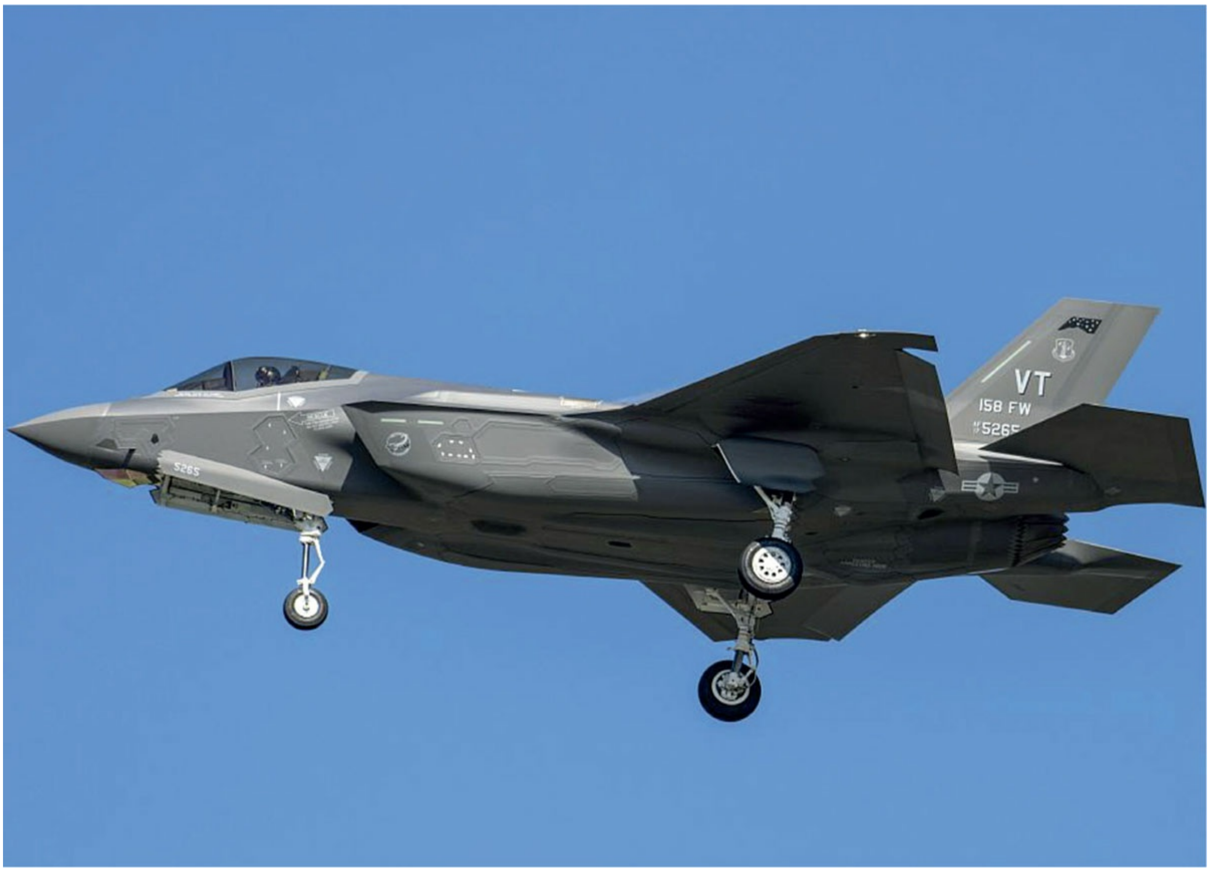
ED
461 FLTS
0744

F-35A 07-0744 drops a small-diameter bomb during weapons tests. This weapons test was one in a series of tests performed with the F35's latest 3F software.

(Lockheed Martin)

01
CF
USS AMERICA
VMFA-211
01

An F-35B Lightning II Short Takeoff Vertical Landing (STOVL) aircraft conducts test operations on the flight deck of amphibious assault ship USS *America* (LHA 6) on 17 November 2016. (US Navy)



F-35A 17-5265 is destined for the 134th Fighter Squadron. This is the first F-35 to be assigned to an Air National Guard unit. It was first seen on 31 July 2019 at NAS Fort Worth. (Lockheed Martin)

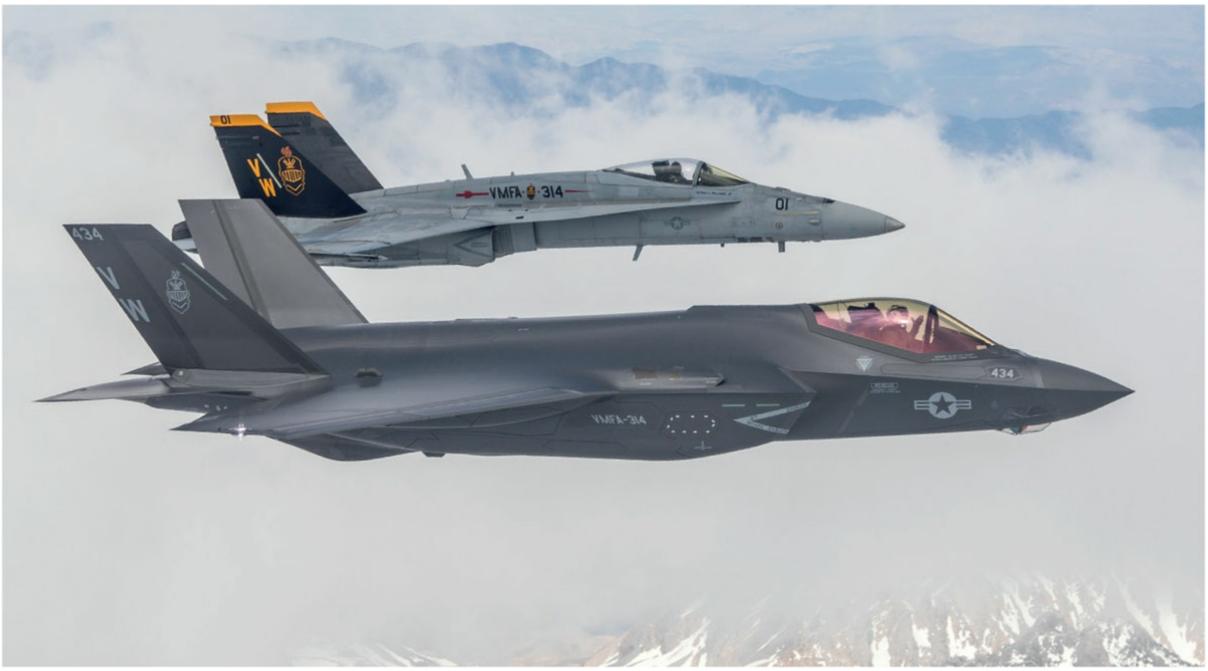
On 5 November 2016 an F-35B Lightning II aircraft launches from the flight deck of amphibious assault ship USS *America* (LHA 6) equipped with inert 500lb GBU-12 Paveway II laser-guided test bombs during flight operations. (US Navy)

USMC F-35B test aircraft just after executing a short takeoff from the deck of the USS *Wasp* on 17 August 2013. (Lockheed Martin)

F-35C Lightning II CF-05 conducts its first arrested landing aboard the aircraft carrier USS *Nimitz* (CVN 68) on 3 November 2014. Nimitz is underway conducting routine training exercises. (US Navy)

A different view of an F-35C Lightning II carrier variant, launching off the flight deck of the aircraft carrier USS *George Washington* (CVN 73). (US Navy)

An F-35C Lightning II fighter jet, attached to the "Argonauts" of Strike Fighter Squadron (VFA) 147, flies in formation for a photo exercise in Lemoore, CA, on 16 November 2018. VFA-147 is the first US Navy operational F-35C squadron based out of NAS Lemoore. (US Navy)



VW
VMFA 314
01
434
VW
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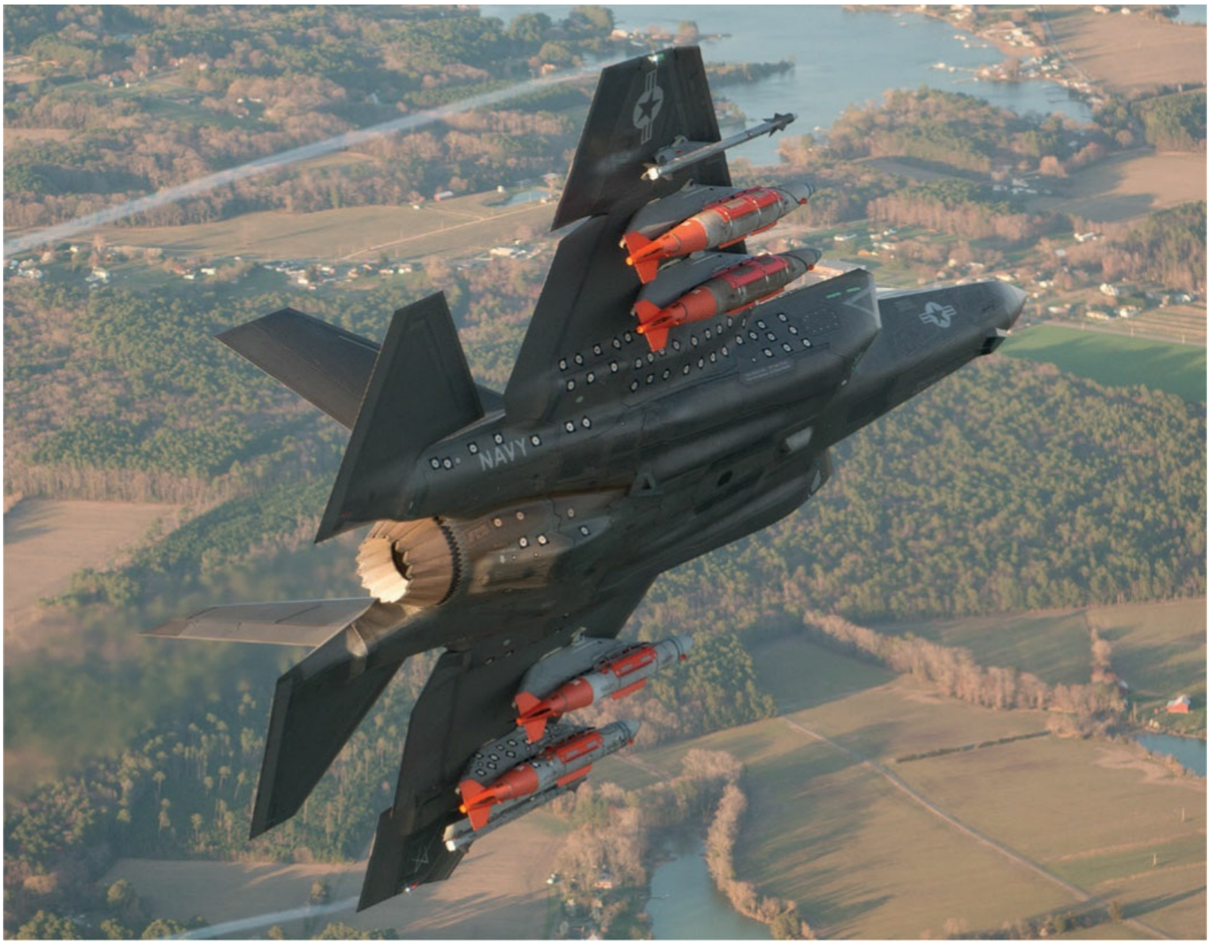
434

On 5 June 2019, the first Marine Fighter Attack Squadron (VMFA) 314 "Black Knights" F-35C aircraft from NAS Lemoore flown by Capt Tommy Beau Locke from Strike Fighter Squadron (VFA) 125 "Rough Raiders" flies in formation over the Sierras with the VFMA 314 Squadron F/A-18A. (US Navy)



Test pilot Billie Flynn pilots an F-35C Lightning II test aircraft during an external GBU-31 and AIM-9X buffet and flutter test flight from NAS Patuxent River on 4 April 2018. (US Navy)

X-33 VENTURESTAR

1996

PROGRAM: X-33

Name: VentureStar

Mission: Single-stage-to-orbit-prototype

Length: 69ft (21.03m)

Wing Span: 77ft (23.47m)

Height: 22ft 3in (6.78m)

Max T.O. Weight: 285,000lb (129,274kg)

First Flight: Proposal only

Last Flight: N/A

Crew: Unmanned

Number Built: N/A

Power Plant: 2 x J-2S Linear Aerospikes fueled by LH2/LO2

Design Speed: Mach 14.33 (11,000mph; 17,703km/h)

Service Ceiling: Low Earth orbit

Combat Radius: 950 miles (825nm; 1,530km)

Weapons Load: Payload to low Earth orbit – N/A

On 2 July 1996, NASA competitively selected Lockheed Martin for a government–industry partnership to design, build and fly the experimental X-33 rocket plane. The X-33 vehicle was to demonstrate advanced technologies to dramatically increase launch vehicle safety and reliability, and to lower the cost of putting a pound of payload into space from $10,000 to $1,000. The X-33 was a half-scale prototype of a reusable launch vehicle (RLV) that Lockheed Martin called the VentureStar. The goal of the program was to demonstrate in flight the technologies needed for a full-size RLV, and thus enable private industry to build and operate the RLV in the first decade of this century.

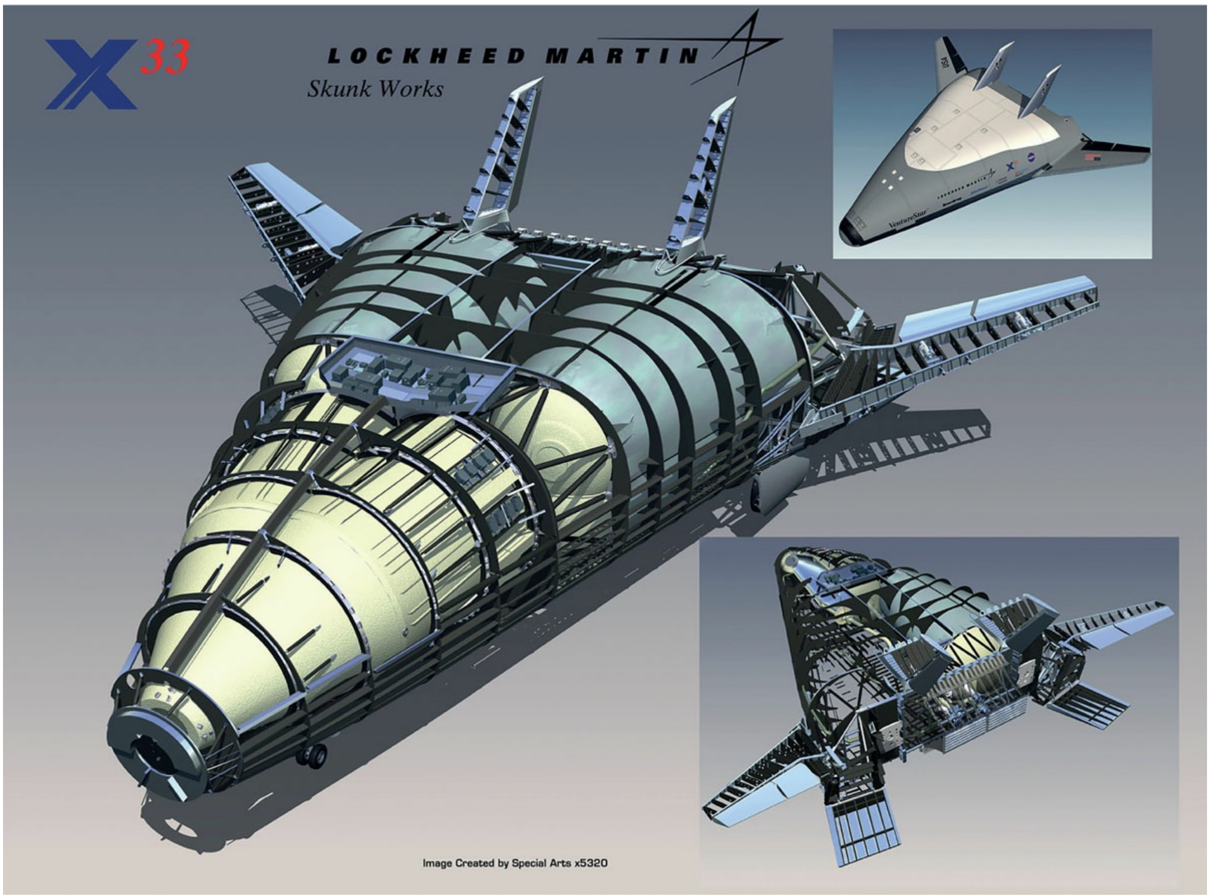
The Lockheed Martin X-33 design was based on a lifting body shape with two revolutionary linear aerospike rocket engines and a rugged metallic thermal protection system. It was intended to be an autonomously piloted vehicle, launched vertically like a rocket, reaching an altitude of 60 miles and speeds faster than Mach 13 (13 times the speed of sound), and landing horizontally like an airplane. Although suborbital, the X-33 would have flown high enough and fast enough to encounter conditions similar to those experienced on an orbital flight path to fully test its systems and performance. Highlighting the vehicle's aircraft-like operations, the X-33 program was to have demonstrated a standard seven-day turnaround, as well as an emergency two-day turnaround, between selected flights.

A series of 15 flight-tests were planned to begin at the turn of the century. Initial flights of 450 miles were to be conducted from Edwards AFB, to Dugway Proving Ground, Utah. As officials gained increased confidence in the vehicle's performance, plans were to call for more challenging 950-mile flights from Edwards AFB to Malmstrom AFB, Montana. Before cancelation, NASA had budgeted $941 million for the X-33 program.

The program was canceled in February 2001. The main reason for this was reported as a delay in completing the fuel tanks which would have allowed the X-33 to fly to low Earth orbit without the need for the sort of external boosters and fuel tanks used by the Space Shuttle.

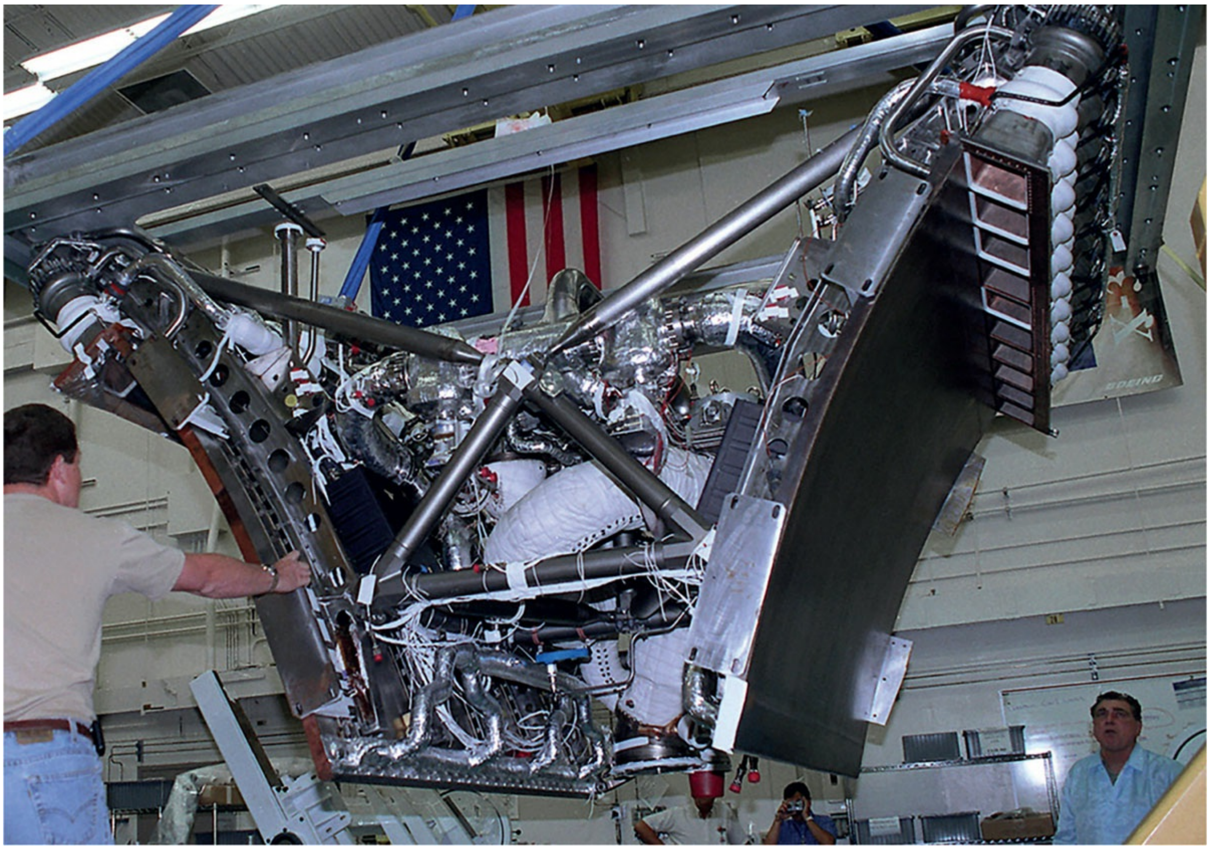
The industry team included the lead, Lockheed Martin, AlliedSignal Aerospace, Boeing, Rocketdyne, B. F. Goodrich Aerospace and Sverdrup. The government team included NASA's Marshall Space Flight Center, Ames Research Center, Dryden Flight Research Center, Goddard Space Flight Center, Jet Propulsion Laboratory, Johnson Space Center, Kennedy Space Center, Langley Research Center, Lewis Research Center and Stennis Space

Center.

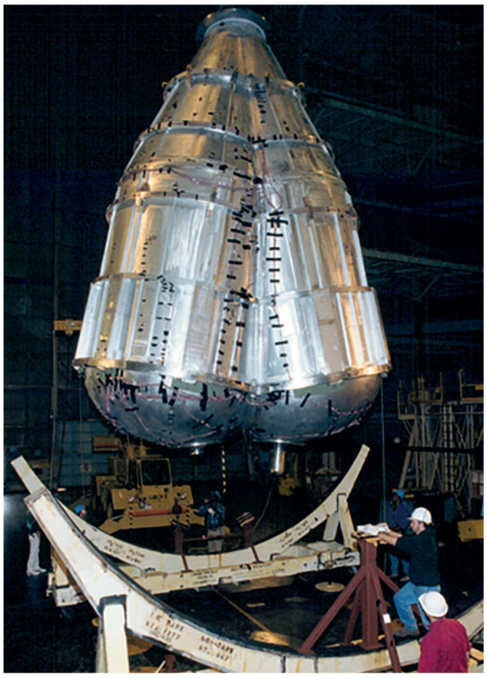

X33
LOCKHEED MARTIN
Skunk Works
Image Created by Special Arts x5320

NASA selected Lockheed Martin to design, build, and fly the X-33 Advanced Technology Demonstrator test vehicle between March and December 1999. The X-33, a half-scale vehicle for VentureStar, was expected to feature a lifting-body shape, a new "aerospike" rocket engine, and a rugged metallic thermal protection system. It was expected to demonstrate in flight the new technologies needed for a reusable launch vehicle (RLV). (Lockheed Martin)

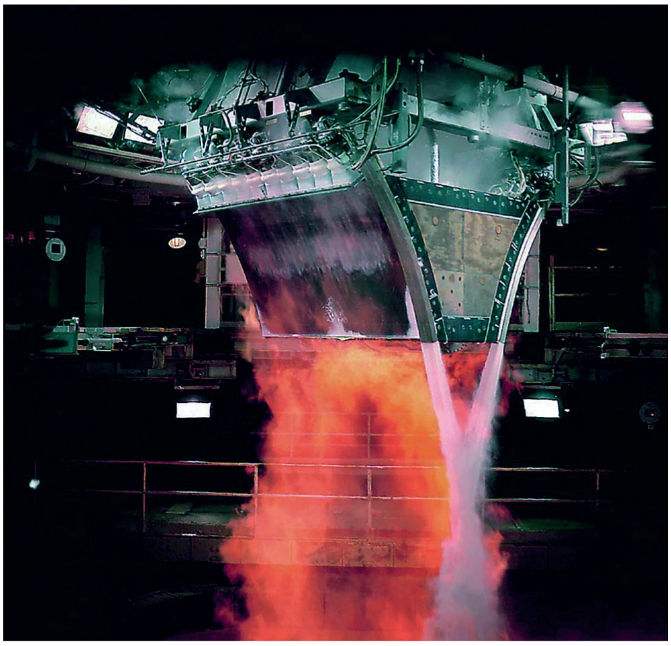
The Lockheed Martin X-33 was an unmanned, sub-scale technology demonstrator suborbital spaceplane developed in the 1990s under the US government-funded Space Launch Initiative program. (Lockheed Martin)



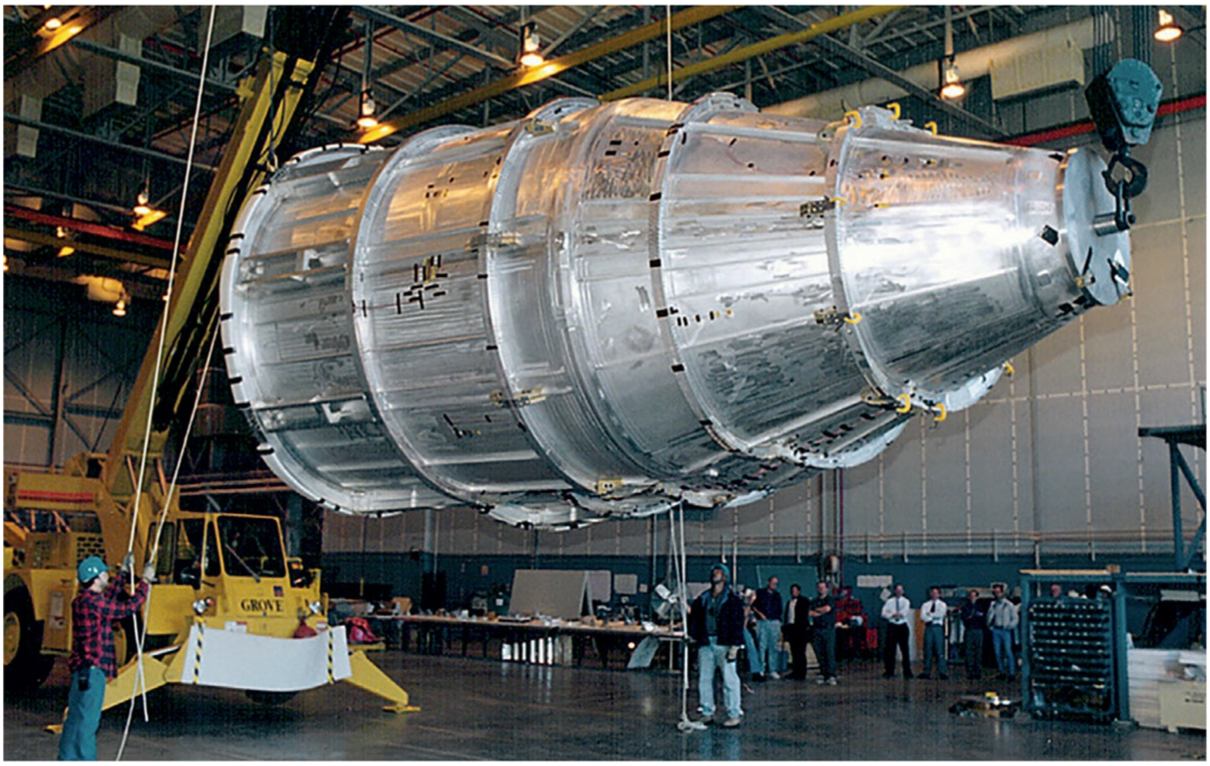
The X-33's aerospike engine. The X-33 would flight-test a range of technologies that NASA believed it needed for single-stage-to-orbit reusable launch vehicles (SSTO RLVs), such as metallic thermal protection systems, composite cryogenic fuel tanks for liquid hydrogen, the aerospike engine, autonomous (unmanned) flight control, rapid flight turn-around times through streamlined operations and its lifting body aerodynamics. The X-33 contract was awarded to Lockheed Martin in 1996, and $1 billion was spent through 1999. (Lockheed Martin)



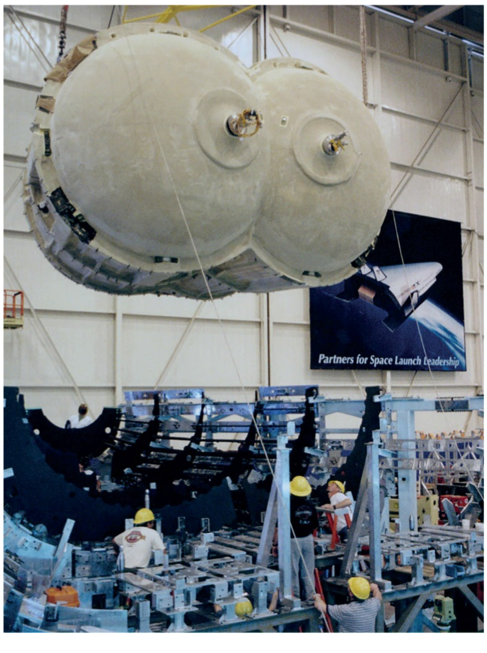
X-33 liquid oxygen (LOX) tank at the Michoud NASA rocket engine testing complex during October through November 1997. (Lockheed Martin)

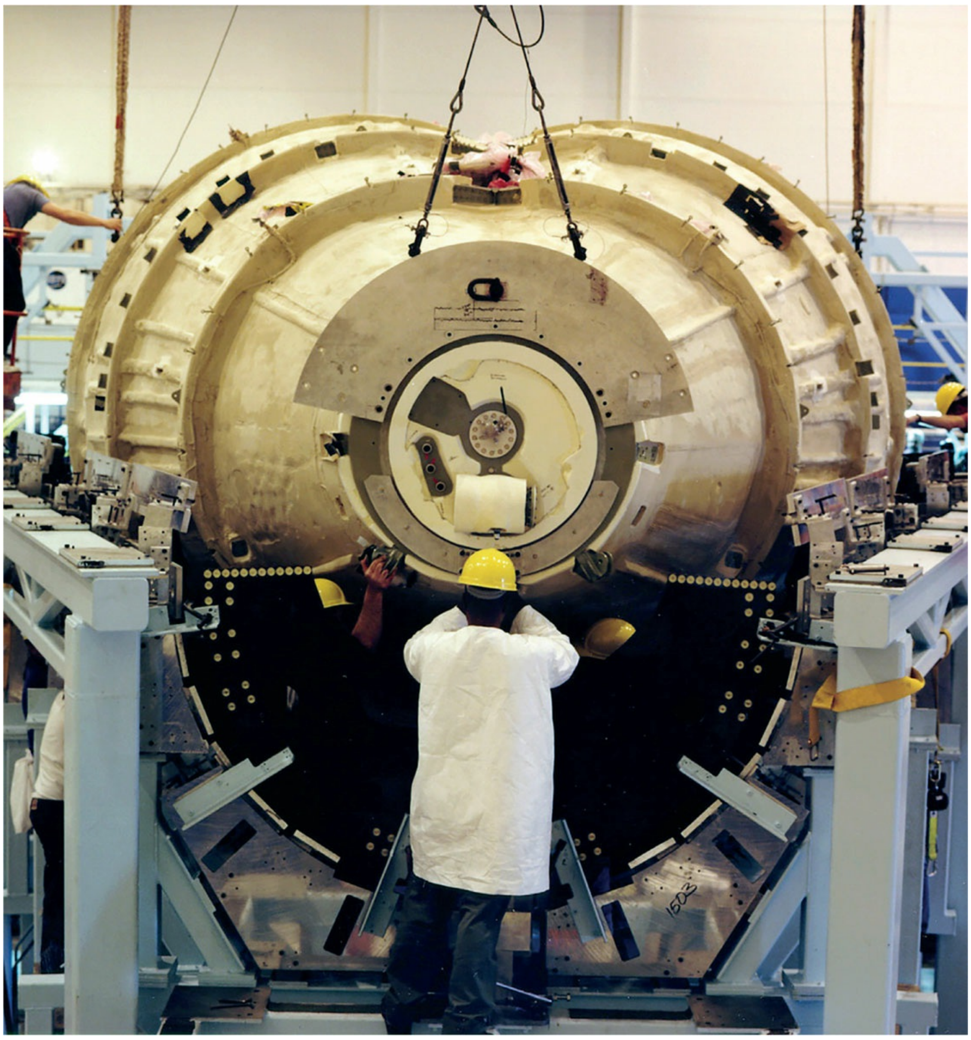


XRS-2200 linear aerospike engine for the X-33 program being tested at the Stennis Space Center. (Lockheed Martin)

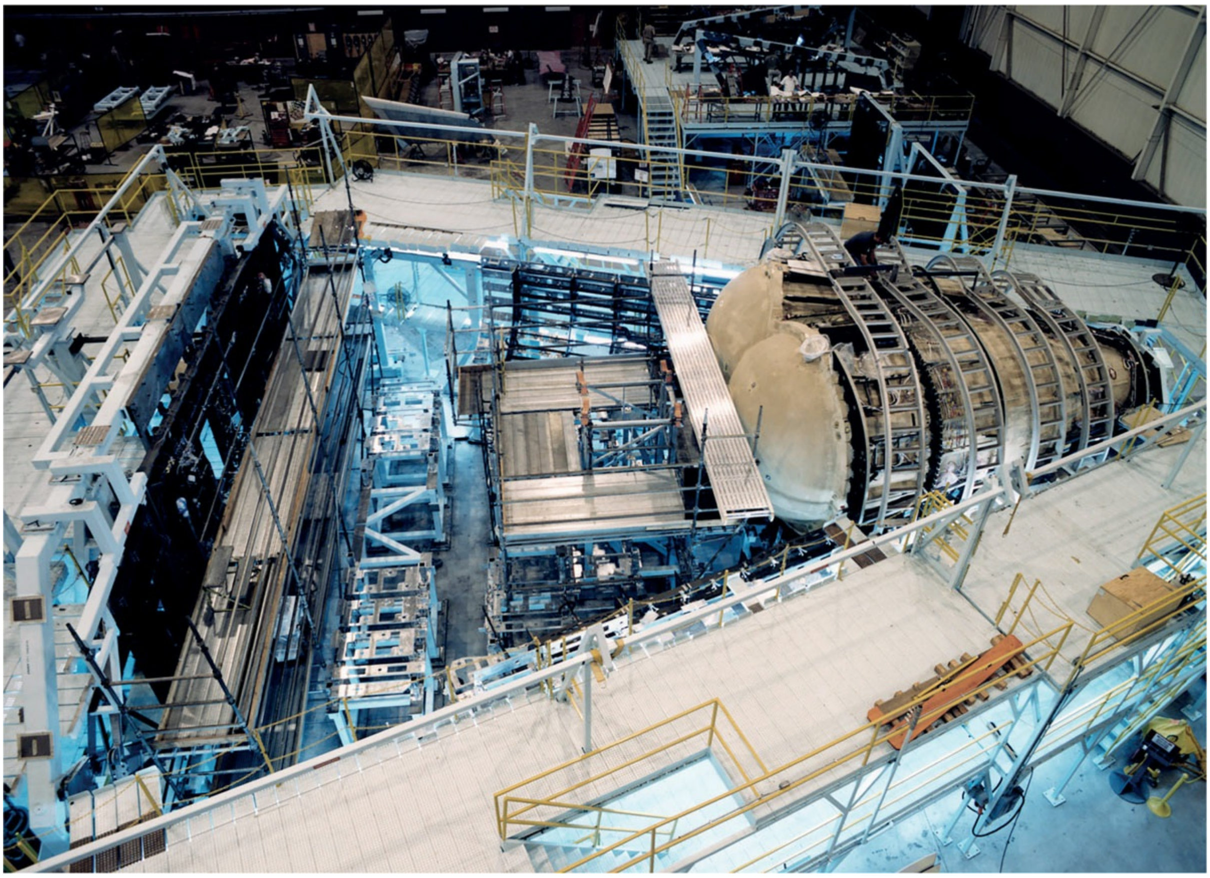


X-33 LOX tank in Michoud Assembly Facility in October through November 1997. (Lockheed Martin)

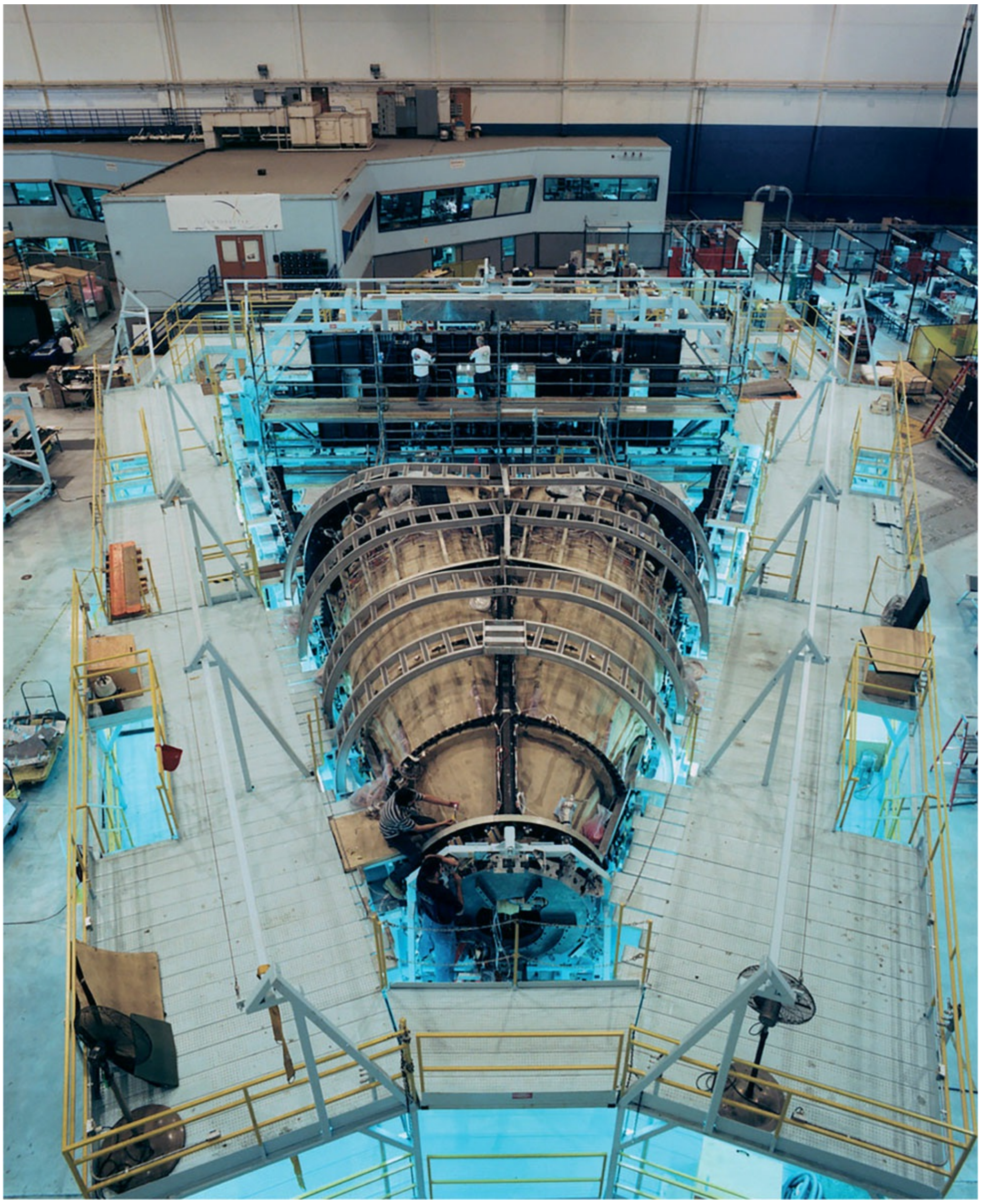

Partners for Space Launch Leadership



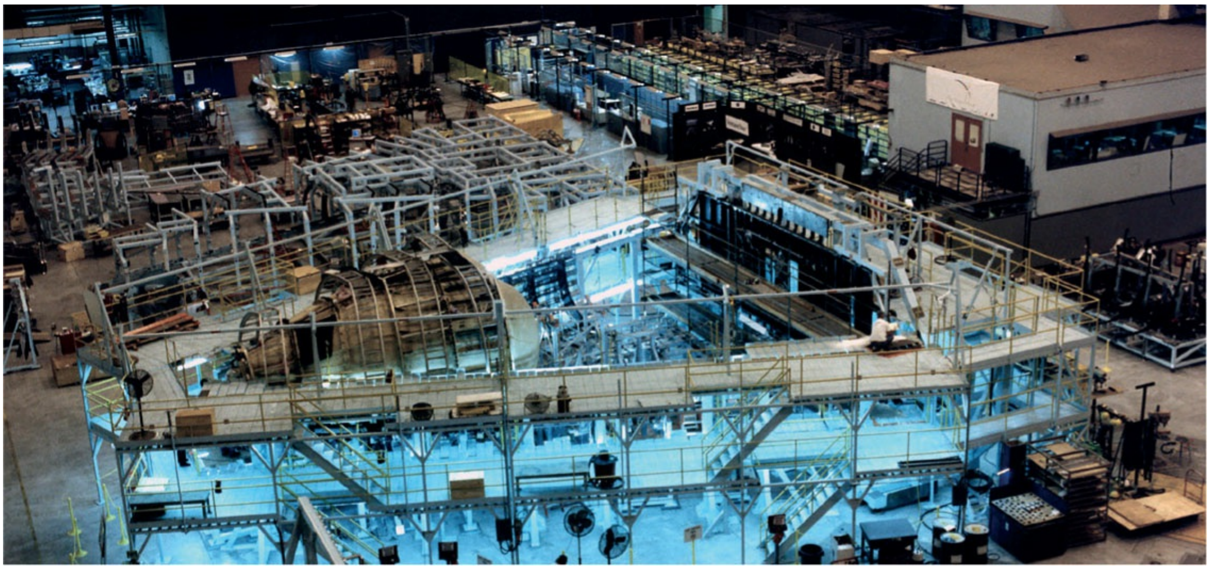
X-33 LOX tank installation in B-704, Palmdale. (Lockheed Martin)



X-33 assembly in B-704, Palmdale on 17 May 1999. (Lockheed Martin)

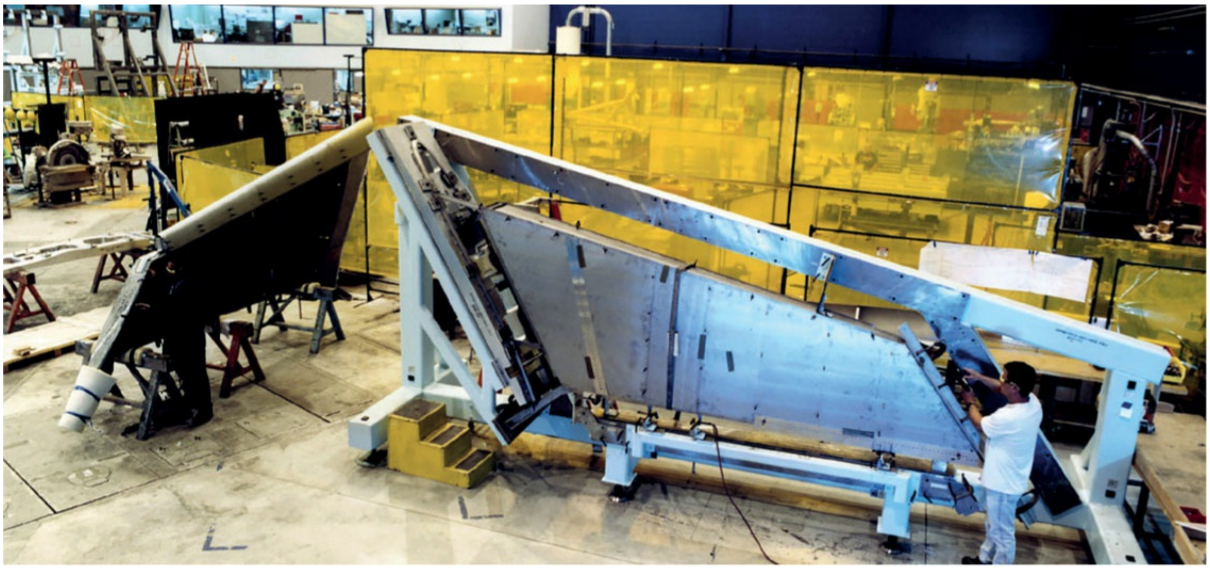


Looking down on the X-33 production in Building 704 at Air Force Plant 42, Site 7 in Palmdale on 17 May 1999. (Lockheed Martin)

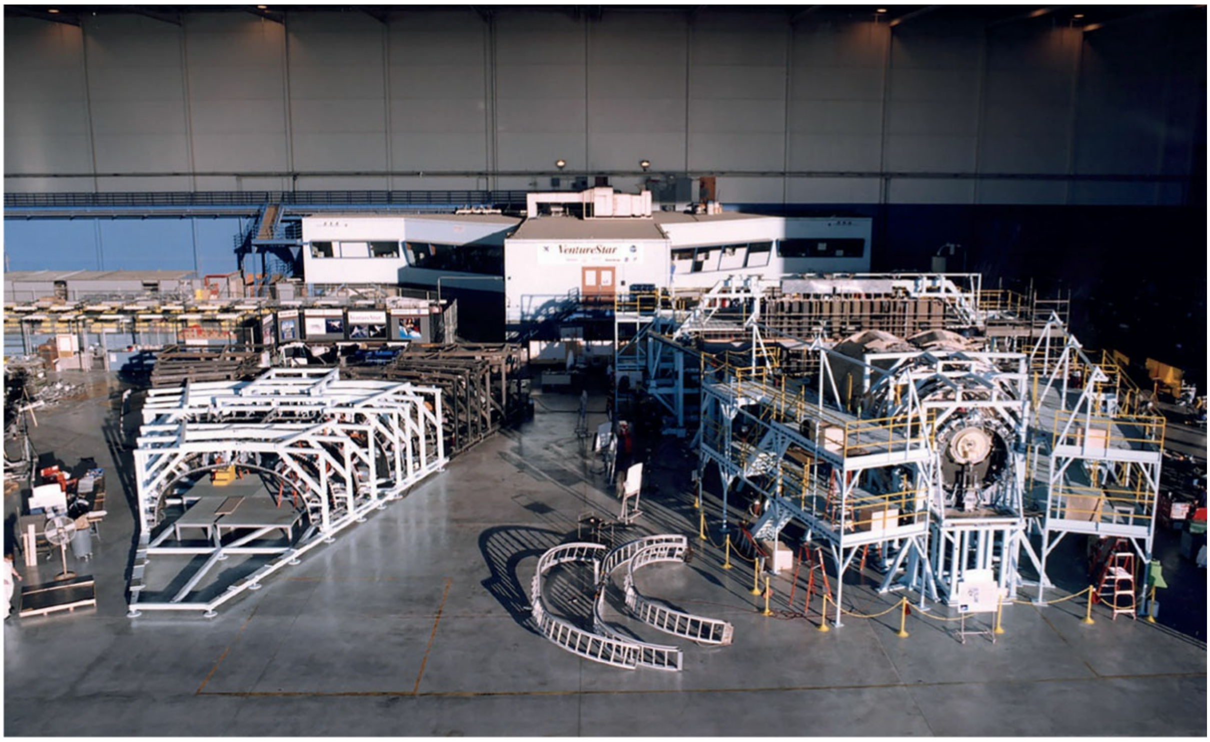


X-33 production in B-704 with the liquid hydrogen and liquid oxygen installed at Site 7 in Palmdale on 17 May 1999. (Lockheed Martin)

X-33 assembly with production tooling surrounding the aft fuselage section in B-704, Palmdale. (Lockheed Martin)

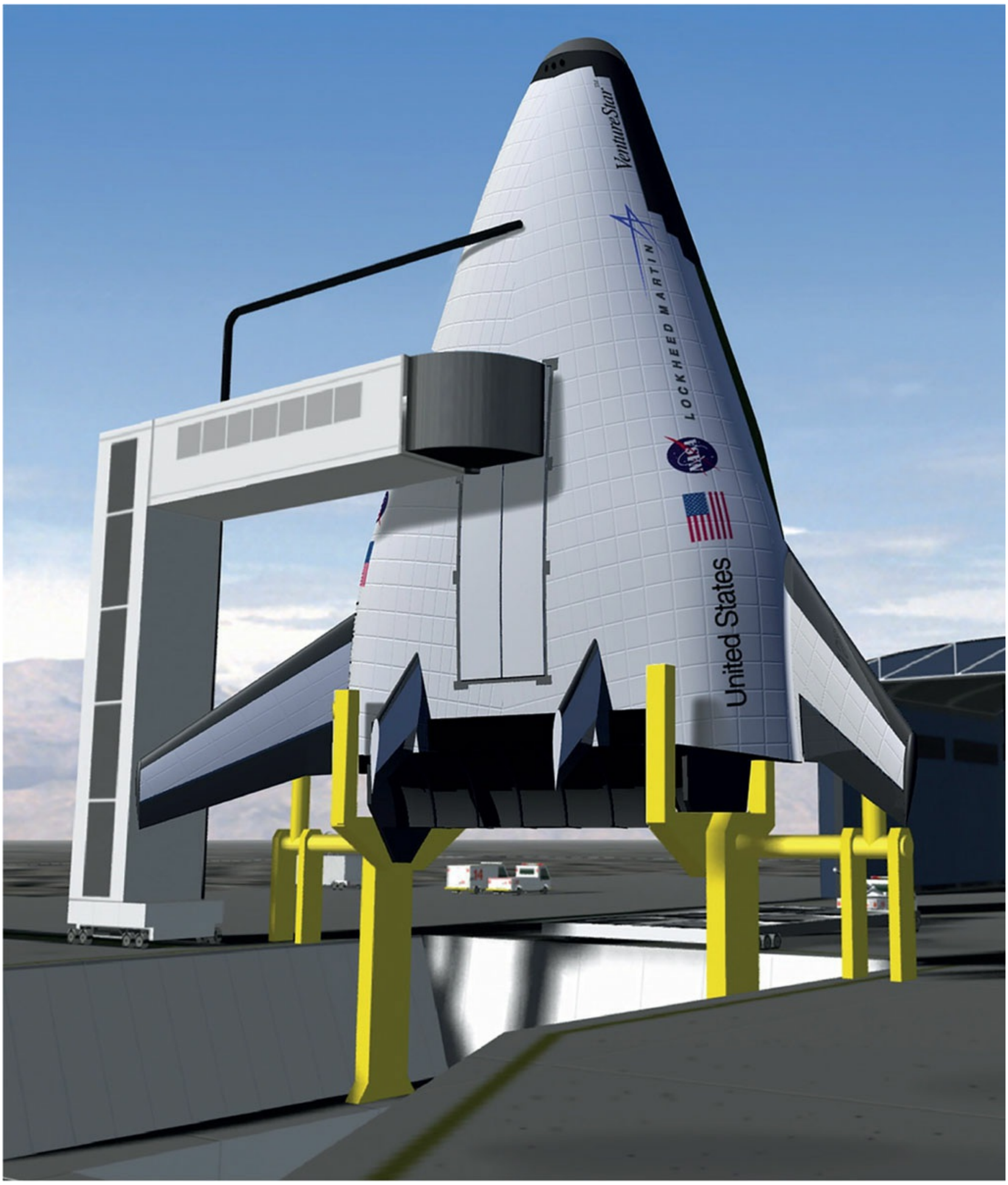


X-33 assembly of body flaps and vertical tail in B-704, Palmdale, 17 May 1999. (Lockheed Martin)

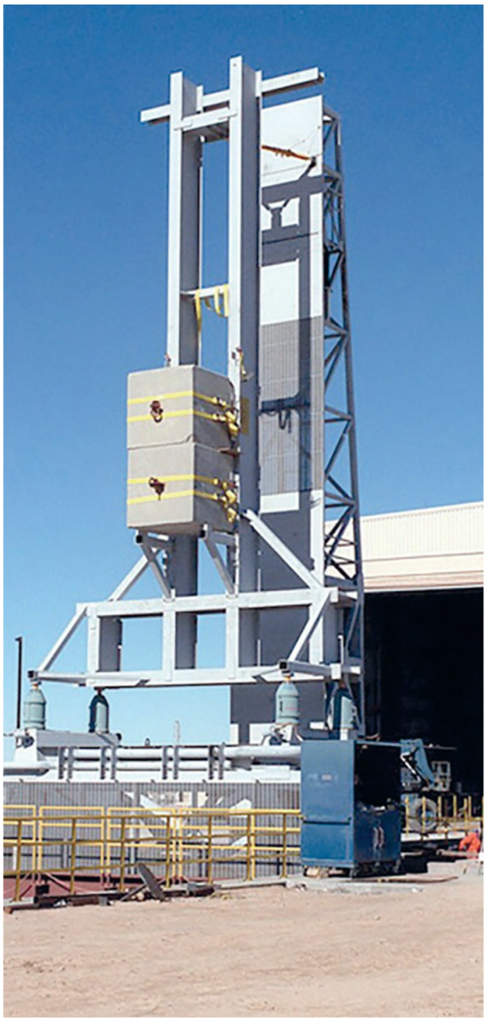


X-33 assembly in B-704, Palmdale, on 24 July 1998. The tanks are installed and some of the assembly fixtures have been taken off the partially completed X-33 Advanced Technology Demonstrator test vehicle. (Lockheed Martin)

X-33 alerion assembly fixture; a Lockheed Martin technician puts the finishing touches on the assembly in B-704, Palmdale. (Lockheed Martin)


VentureStar
LOCKHEED MARTIN
NASA
United States

X-33 proposal artwork depicting the X-33 in its launch and crew access facility at the north end of the Edwards AFB complex near the rocket test site on the east shore of Rogers Dry Lake. (Lockheed Martin)



X-33 launch site in the eastern portion of Edwards AFB showing the launch and position assembly being put through its paces with ballast attached to the lift/launch gantry. (Lockheed Martin)

RQ-3 DARKSTAR

1996

PROGRAM: RQ-3A

Name: DarkStar – Tier III-

Mission: High-altitude long endurance UAV

Length: 15ft (4.6m)

Wing Span: 69ft (21m)

Height: 3ft 6in (1.1m)

Max T.O. Weight: 8,500lb (3,860kg)

First Flight: 29 March 1996

Last Flight: 29 January 1999

Crew: Unmanned

Number Built: 4

Power Plant: 1 x Williams/Rolls-Royce FJ44-1A turbofan

Design Speed: Mach 0.38 (288mph; 464km/h)

Service Ceiling: 65,000ft (19,812m)

Combat Radius: 575 miles (500nm; 925km)

Weapons Load: Flight-test article

The DarkStar unmanned aerial vehicle (UAV) was developed for DARPA's "Tier III-" requirement for a low-observable high-altitude endurance (LO-HAE) UAV. "Tier III-" itself was a downgraded variant of the "Tier III" specification, which called for a larger and more complex vehicle. "Tier III" was abandoned because of too many technological and financial risks. The Advanced Concept Technology Demonstration (ACTD) contract for the "Tier III-" UAV was awarded to Lockheed Martin in June 1994. A major subcontractor with a 50 percent share was Boeing, which was responsible for wing development and production. The first flight was originally intended to occur in October 1995, but was delayed by software problems until March 1996. However, the program was stopped again after the first prototype crashed on takeoff for its second flight in April that year because of a control system malfunction leading to pitch-up and stall. In January 1997, the DarkStar was officially designated RQ-3A, and in June 1998, flight-testing finally resumed with the second RQ-3A vehicle.

Lockheed Martin, Boeing and DARPA developed the stealthy, low-observable DarkStar to provide sustained reconnaissance information from anywhere within enemy territory, day or night, in all types of weather. Developed concurrently with the non-stealthy RQ-4A Global Hawk, DarkStar could provide near real-time target data and imagery by way of satellite links to its mobile ground station.

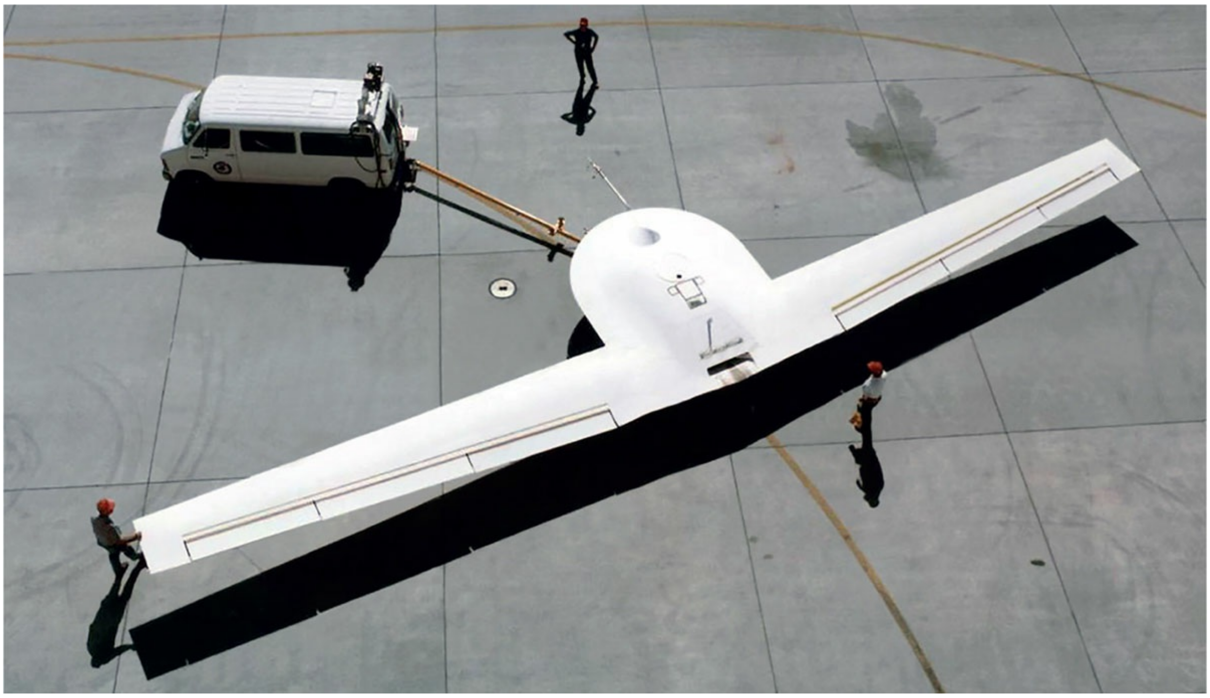
The RQ-3A was a low-observable flying-wing design with a very slightly forward-swept wing and a "flying saucer"-shaped fuselage section. It was powered by a single Williams F129 (Model FJ44-1A) turbofan engine, and could cruise for about 12 hours at an altitude of up to 65,000ft. For the planned fully autonomous missions, the DarkStar was equipped with a GPS/INS navigation system, which could be retasked in flight. Communication was done via two-way datalinks (command and control uplink, sensor data downlink), either a wideband line-of-sight link or a J-band SATCOM link. The payload bays in the lower fuselage could accommodate various types of sensors, but the primary options were: a Northrop Grumman AN/ZPQ-1 TESAR (Tactical Endurance Synthetic Aperture Radar) surveillance radar or a Recon/Optical CA-236 electro-optical camera system.

The problems and delays of DarkStar led to rising costs, and in January 1999 the USAF decided that the advantages of the RQ-3A did not justify the continuation of testing, and the program was canceled in 1999, with the two

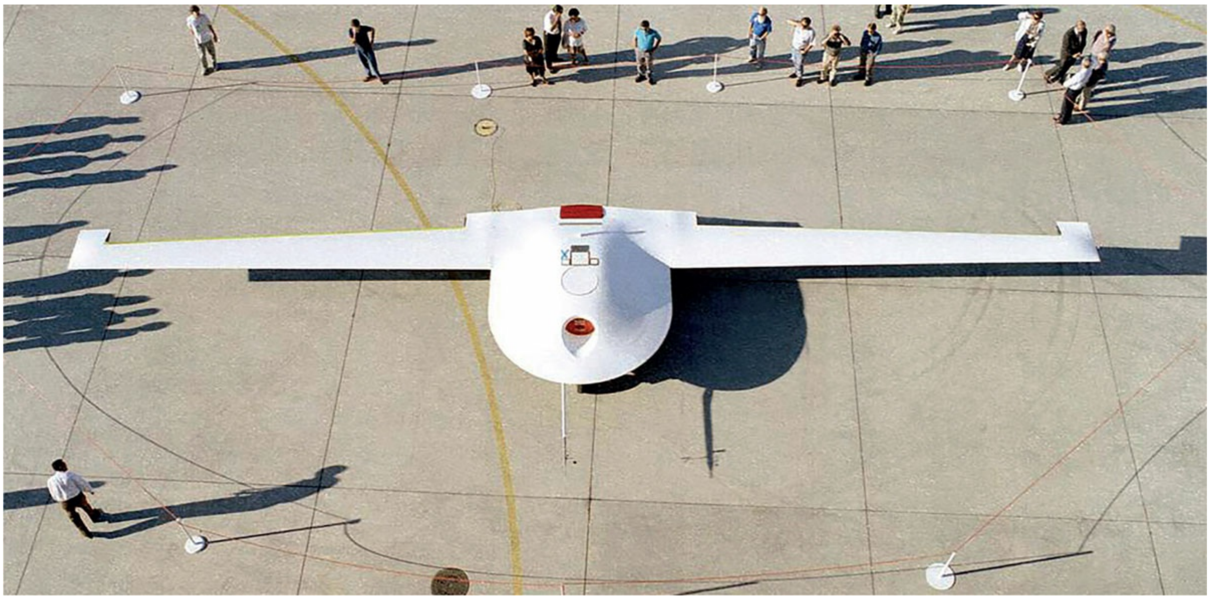
DarkStar ACTD vehicles remaining the only RQ-3As built.

At the time, the common story within the aviation community was that the aircraft was not able to meet design requirements so the program was abandoned; however, many thought this was actually a cover story to hide the DarkStar's great potential. Whatever the truth of the matter, the prototypes were sent to museums and the program was abandoned, at least to public view.

However, the official 1999 program cancelation was not quite the end of the story, because during Operation Iraqi Freedom in March/April 2003, the USAF acknowledged the operational use of at least one prototype of a new stealthy high-endurance UAV. It was a scaled-up and more capable derivative of the DarkStar, but nothing more has been revealed about this UAV.



The first RQ-3A, AV-1, is pulled out to Rogers Dry Lake bed for a test flight. On 29 March 1996, DarkStar made its first flight. It reached an altitude of 5,000ft and successfully executed a fully automated flight from takeoff to landing using the Global Positioning System. (Lockheed Martin/Boeing)

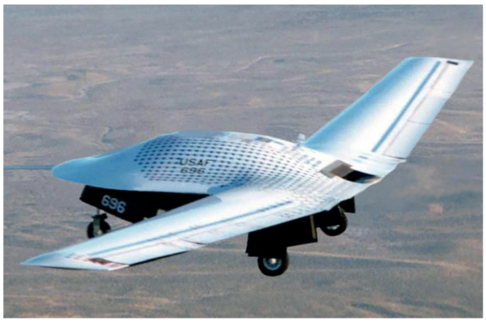


The RQ-3/DarkStar roll out is viewed from above in this photo of 14 September 1997. The RQ-3 was a joint government and industry effort. In 1994, Boeing teamed with Lockheed Martin to design and build DarkStar. (USAF)

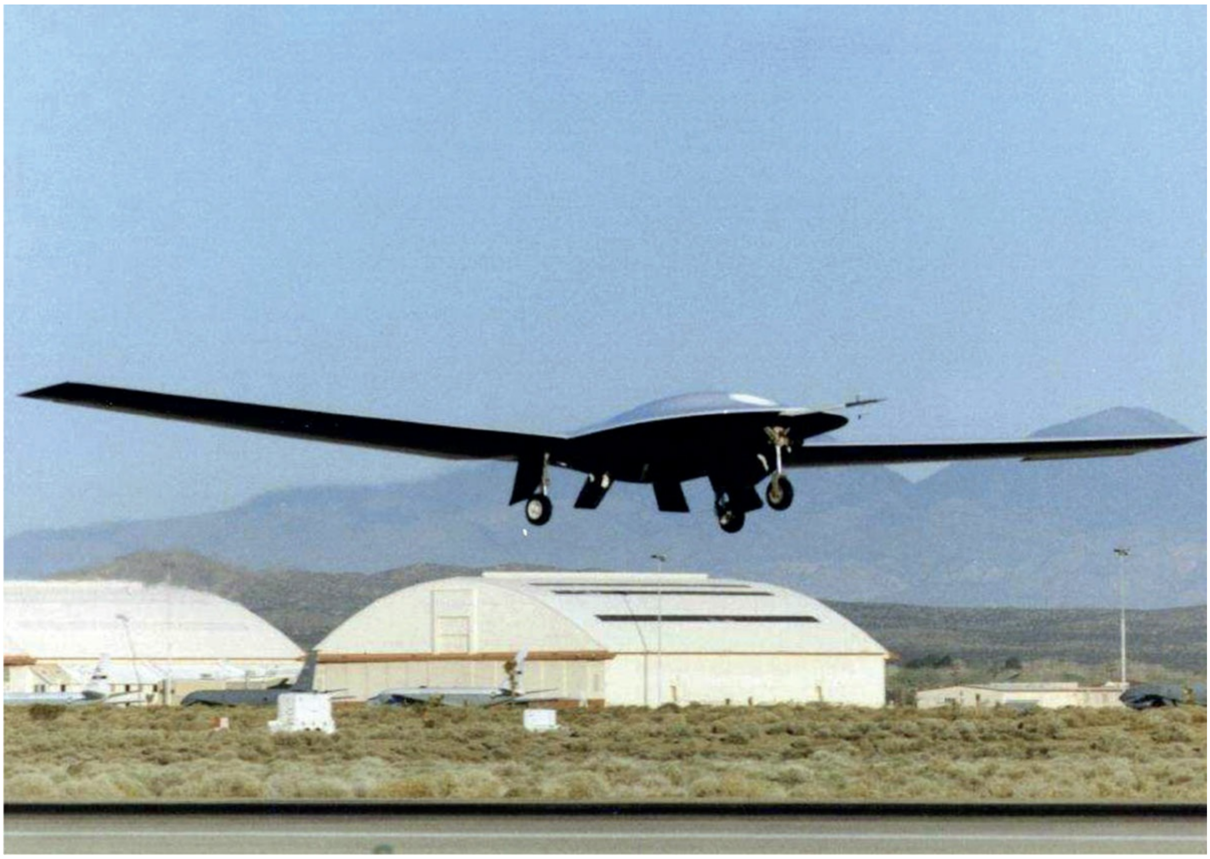
The RQ-3 is an unmanned reconnaissance plane called DarkStar for the US

Department of Defense "Tier III-" program. Boeing developed the DarkStar's wings and integrated avionics. (Lockheed Martin/Boeing)

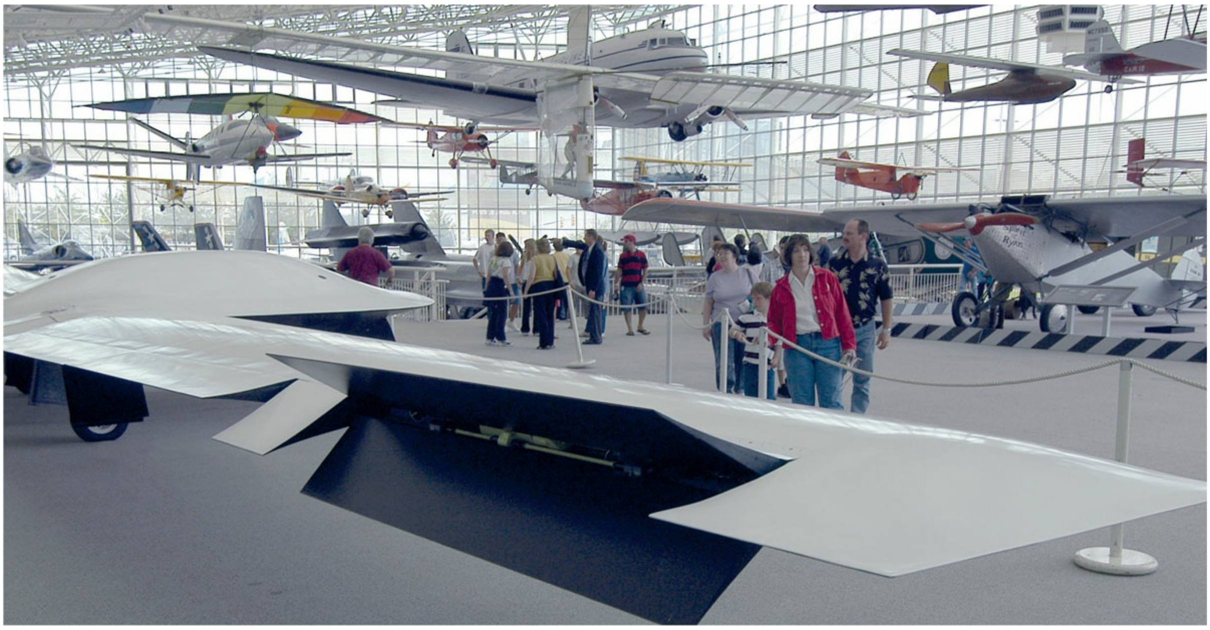
Two of the four Lockheed Martin RQ-3A DarkStar unmanned aerial vehicles (UAVs) built are shown packed in a C-5B Galaxy on their final flight from Palmdale to the USAF Museum at Wright-Patterson AFB, in December 1999. (USAF)



Dark Star RQ-3A AV-1 is seen with wind tuffs on the port side of the RQ-3's forward fuselage. (Lockheed Martin/Boeing)



RQ-3A, AV-1, lifts off the Edwards AFB main runway on its very first flight on 29 March 1996. (Lockheed Martin/Boeing)



Assembly finished and on public display for the very first time on 23 August 2004. It was exhibited with the split alerions in the open position. It was later suspended just to the rear of the Gossamer Explorer. (James C. Goodall)

The author's son James and Evan Elliott position the fuselage of the RQ-3A so it can be wheeled over to where the wing attachment will take place. (James C. Goodall)

X-44A MANTA

2001

PROGRAM: X-44A MANTA

Name: MANTA

Mission: High-altitude UAV technology demonstrator

Length: 9ft (2.74m)

Wing Span: 30ft (9.14m)

Height: 3ft 9in (1.14m)

Max T.O. Weight: Unknown

First Flight: 2001

Last Flight: Unknown. (On display at the NMUSAF)

Crew: Unmanned

Number Built: 1

Power Plant: 1 x Williams/Rolls-Royce F112-1A turbojet

Design Speed: Mach 0.38 (288mph; 464km/h)

Service Ceiling: 35,000ft (10,700m)

Combat Radius: Unknown

Weapons Load: Flight-test article

An aircraft that represents a missing technological link between Lockheed's abortive Tier III-RQ-3A DarkStar UAV and the company's history-making RQ-170 Sentinel is now coming to light. The Lockheed Skunk Works built this previously classified flying-wing drone in 1999, shortly after the RQ-3 program vanished.

This new program, which aimed to prove rapid manufacturing technologies and penetrating aerial reconnaissance capabilities, as well as the aerodynamic validity of a relatively small, tailless, swept-wing drone, was dubbed the X-44A and the first aircraft took to the skies in 2001.

The shadowy aircraft's designation is outright confusing as the X-44 MANTA is largely known as a program that aimed to test a tailless manned aircraft design that originated from the same period of time. This notional aircraft would use thrust vectoring for primary flight control, with the objective being to realize new speed, fuel efficiency and maneuverability capabilities with such a design, as well as to demonstrate simpler and cheaper forms of aircraft structures production.

The X-44's skin was supposedly made out of nano-carbon fiber and a Williams F112 turbojet engine powers it. The F112 power plant is used in cruise missiles, such as the former General Dynamics Stealthy ACM-129 Advanced Cruise Missile.

Size-wise, the X-44 had a wing span of approximately 30ft, making it roughly a third of the size of its RQ-170 successor. The airframe was modular in nature with a potato-like fuselage that could carry various sensors. It is also likely that the aircraft could have its wings detached for transport, similar to the RQ-170. The aircraft was guided by traditional control surfaces along its trailing edge and it featured raked and squared-off wing tips.

Aside from doing independent research for Lockheed Martin, the X-44 was apparently also part of some sort of competition between Boeing, Northrop Grumman and Lockheed; the outcome of this remains unknown but it seems as if Lockheed lost. The goal of that competition is also unknown, but it could have been an early semi-disposable stealthy drone program very similar to the Air Force Research Lab's current Low-Cost-Attritable Strike Demonstrator (LCASD) initiative.

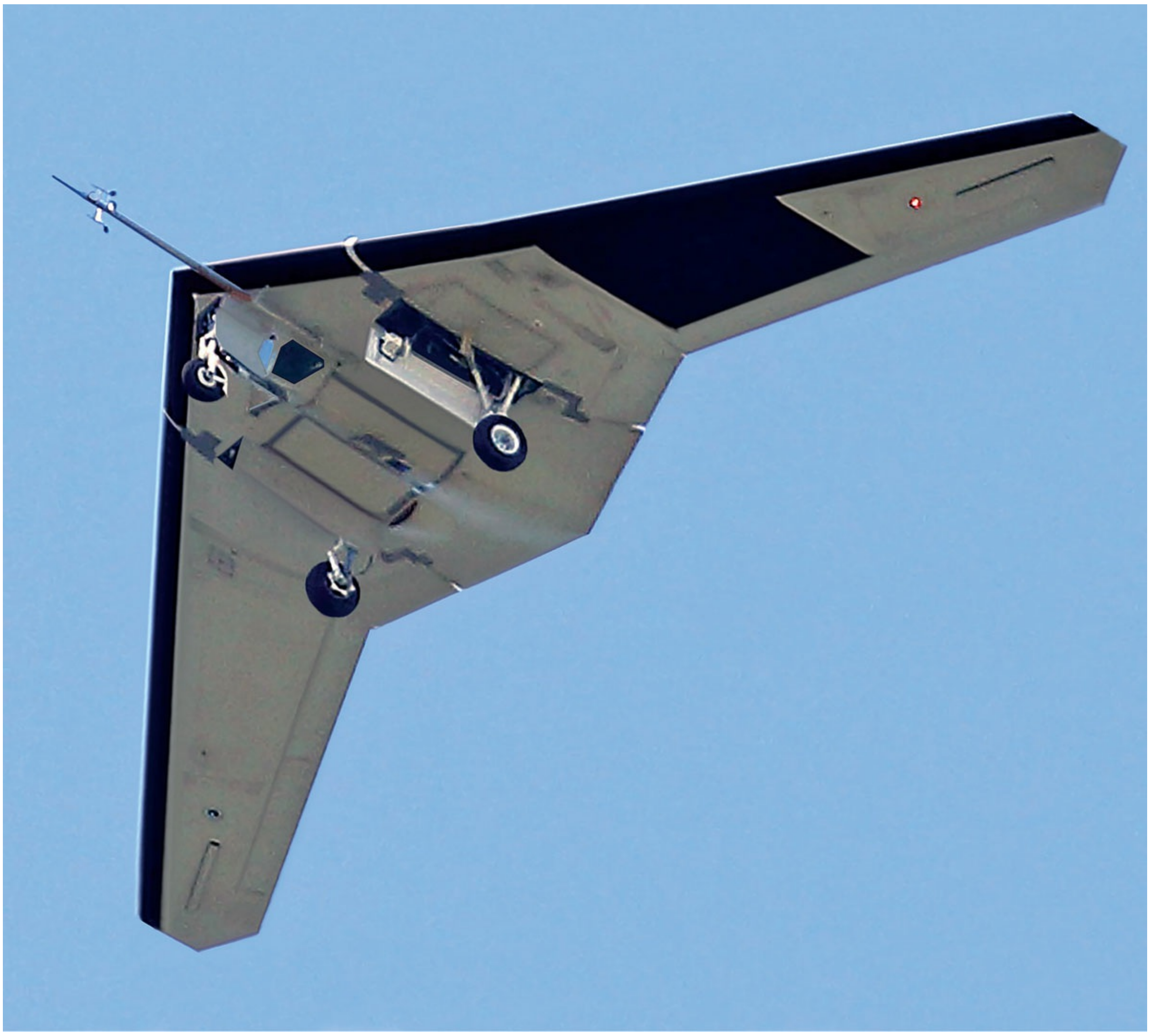
In recent years, the Skunk Works X-44 was refitted and used to evaluate visual cueing systems for the Navy's Carrier Based Aerial Refueling System (CBARS) tanker drone program.

What the X-44 provided Lockheed Martin with is a new evolutionary stepping stone in a lineage of aircraft that collectively represent the Skunk Works' quiet dive into the high-end unmanned space, a space that became increasingly promising in the early 2000s.

The type likely served as one of the cruder forerunners to a family of stealth unmanned aircraft systems, some of which are undoubtedly still cloaked in secrecy. But one can clearly see how it helped spawn the P-175 Polecat demonstrator, which had similar program goals and overall similar design, but on a much larger and more advanced scale.

Other aircraft also likely existed during the early and mid-2000s that are part of this family of clandestine flying-wings courtesy of the Skunk Works. Following the attacks on 9/11, a penetrating and persistent reconnaissance capability would have been a top priority, and it is widely understood that a similar clandestine aircraft system belonging to Lockheed participated in Operation Iraqi Freedom. This was probably a semi-operational forerunner to the RQ-170 Sentinel, which first appeared publicly at Kandahar airfield in Afghanistan in 2007.

The RQ-170 Sentinel in particular, which helped in finding and finishing off Osama Bin Laden, kept tabs on Iran's nuclear program and famously fell into the hands of the Iranians in 2011, not to mention also likely flying missions over other hostile territories such as North Korea, is a known operational benefactor of the X-44A's existence, and there surely are others. Above all else, the nearly two-decade old X-44A serves as a reminder that there is so much technology and history buried in the deeply classified "black" world that we have yet to learn about.

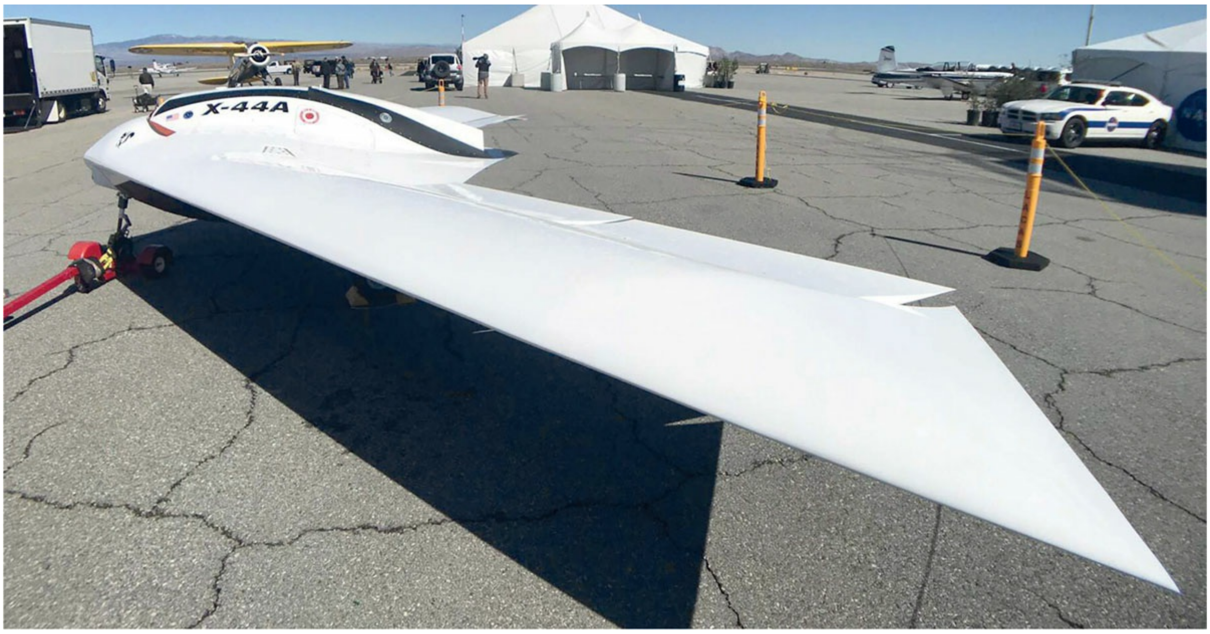


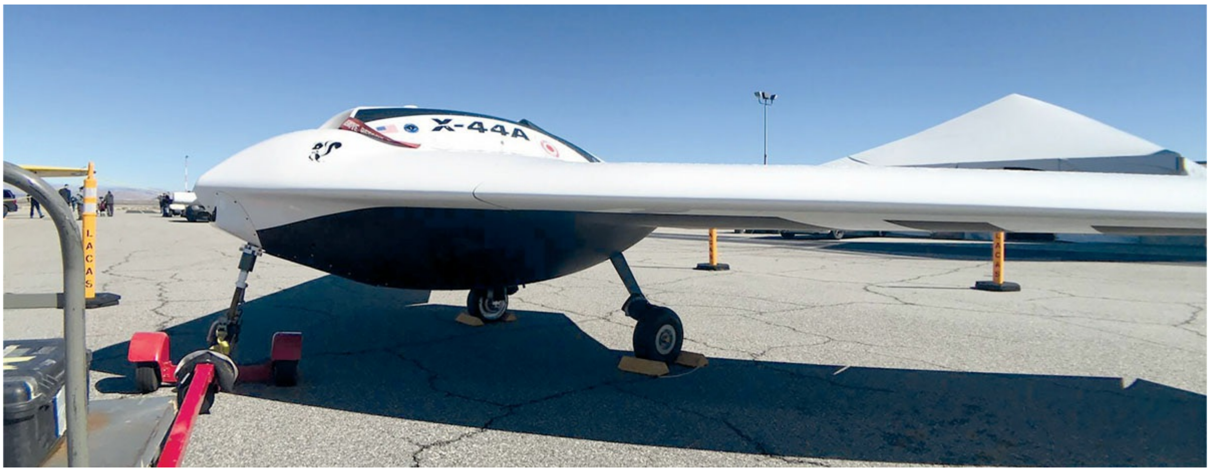
The X-44A was designed and built to reduce risk for future unmanned systems, and is a technology demonstrator that expanded Skunk Works UAS expertise that continues today. Until the confirmation of the existence of the X-44A, nothing was known about Lockheed's UAV development activity between the cancellation of the RQ-3 and the first flight of the Polecat UAV demonstrator in 2005. Lockheed decided to reveal the existence of the formerly secret project the X-44A, which was put on public display for the first time at Fox Field, Lancaster, CA, 18 years after it was built and flown. The X-44A made its public debut as a static display at the LA County Airshow, held the weekend of 24 March 2018. This is near the Skunk Works headquarters at Palmdale. The Skunk Works was celebrating its 75th anniversary, and it was the show's major sponsor. The X-44A was previously shown internally to company employees at Palmdale and Fort Worth. (Lockheed Martin)

X-44A
MAINTENANCE ACCESS

STEM TE

X-44A


X-44A


X-44A
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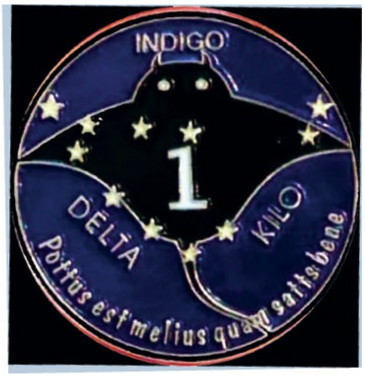
INDIGO
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DELTA
KILO
Potius est melius quam satis bene

X-44A

INER
FWD

DESERT HAWK

2003

PROGRAM: Desert Hawk III

Name: Miniature UAV

Mission: Perimeter Defense

Length: 34in (0.86m)

Wing Span: 52in (1.32m)

Height: 8in (0.2m)

Max T.O. Weight: 7lb (3.2kg)

First Flight: 2003

Last Flight: Still operational

Crew: Unmanned

Number Built: Unknown

Power Plant: Electric motor

Design Speed: Mach 0.04 (28mph; 45.1km/h)

Service Ceiling: 500ft (152.4m)

Combat Radius: Local area patrol

Weapons Load: Approximately 2.2lb (1kg)

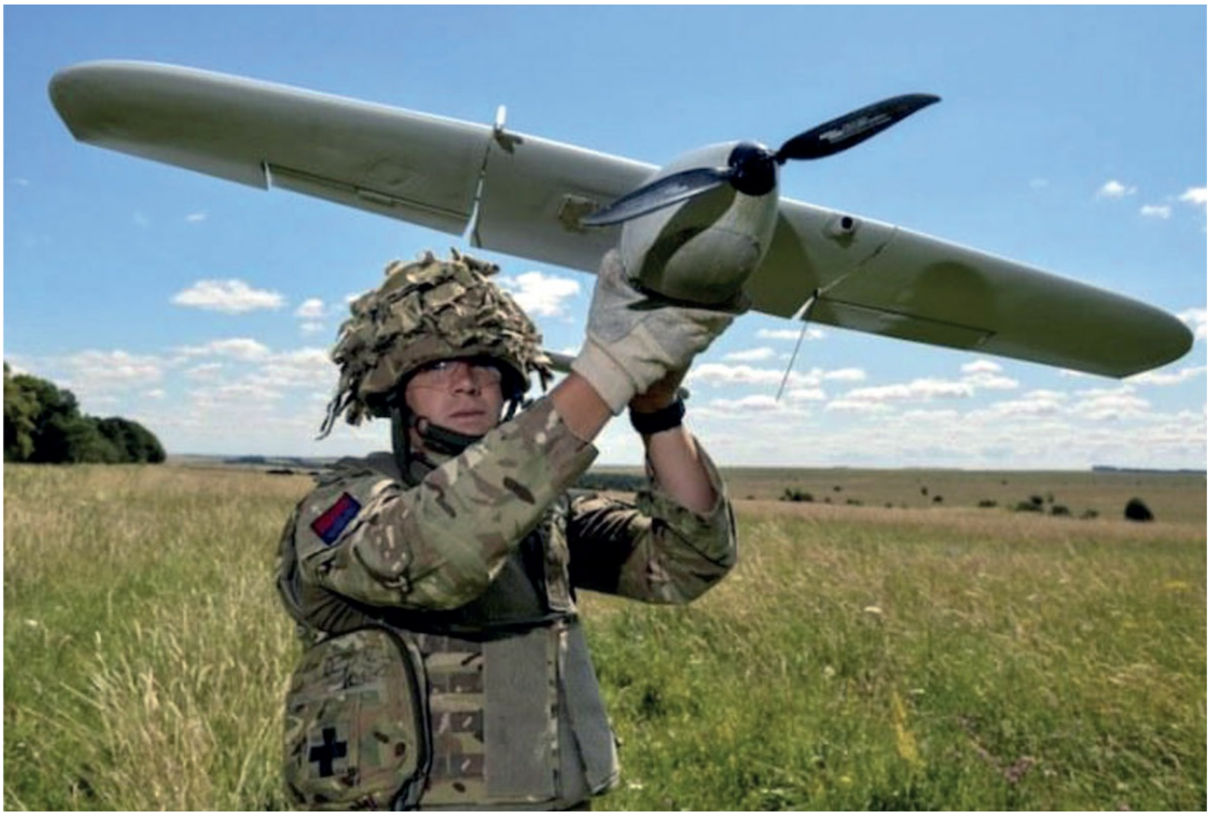
Lockheed Martin’s flagship small unmanned air system (SUAS), Desert Hawk, sets industry standards for performance and mission versatility. Desert Hawk provides day and night support to small unit intelligence, reconnaissance, surveillance, target acquisition and related support operations. Key system attributes include higher wind tolerances and high-altitude flight, as well as extreme temperature operating range, open modular construction and unmatched endurance. This system provides world-class autonomous flight control and lowest audible signature while offering a wide range of commercial- and military-grade communications options.

The combat-proven Desert Hawk SUAS is designed to conduct real-time aerial surveillance with operational ease, mission flexibility and tactical portability. Featuring state-of-the-art 360 degree color electro-optic and infrared full-motion video (FMV) integrated camera systems, as well as other interchangeable plug and payloads, the easy-to-operate Desert Hawk provides all-environment day or night support to small unit information collection, force protection, force support and force application operations. The lightweight, rucksack-portable air vehicles are waterproof, hand-launched and rapidly deployable. The system can be assembled, mission-planned and launched in under ten minutes.

The Desert Hawk family operates in high winds, at extended altitudes and under extreme temperatures. The air vehicles are extremely quiet and virtually undetectable at operational slant ranges. Desert Hawk IV’s improved durability, all-weather operational capability, and longer endurance enable the highest system utilization rates in its class with unmatched reliability in challenging and complex operational environments. Adaptability to mission and inherent growth is a trademark attribute, made possible with Lockheed Martin’s open architecture and modular, interchangeable imaging, communications and electronic warfare payloads. The British army has employed Desert Hawk III for aerial reconnaissance, surveillance and situational awareness tasks since 2006, accumulating tens of thousands of operational flight hours.

Employed in support of combat operations since 2006, Desert Hawk III (DHIII) has made thousands of sorties under austere conditions. The DHIII system includes hand-launched, ruggedized air vehicles with modular, open-architecture, plug and payloads for mission versatility, a portable ground control system and a remote video terminal. The rugged, lightweight ground control station supports preflight operations, rapid and intuitive mission planning and execution, in-flight re-tasking, sensor payload control and real-time video display, record and playback.

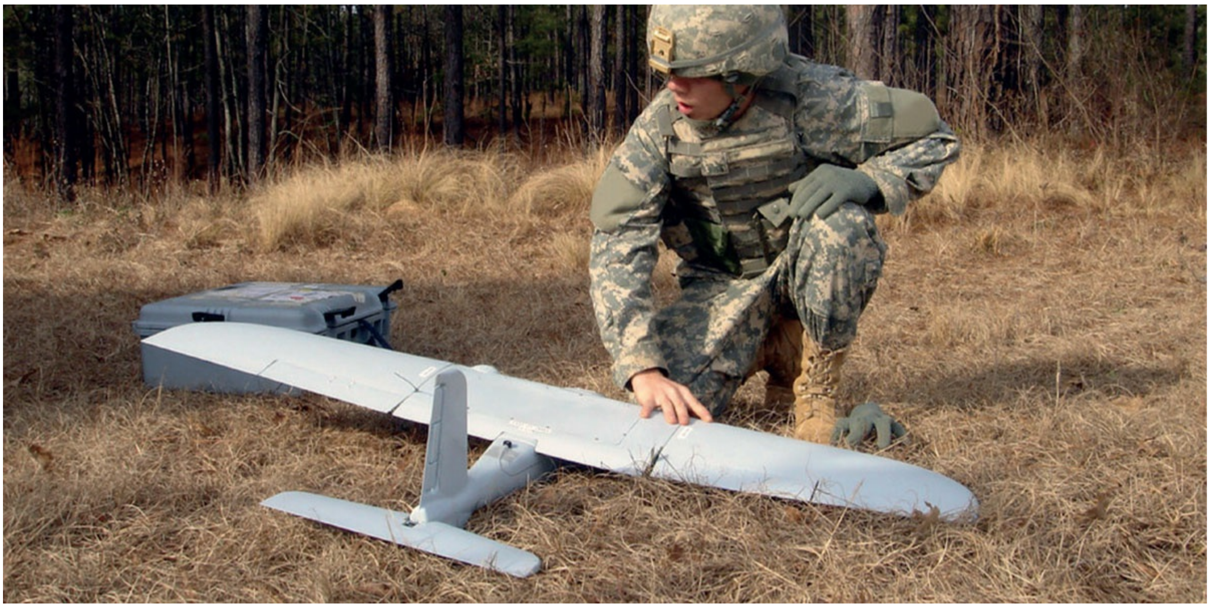
Developed by the Skunk Works of Lockheed Martin, the Desert Hawk III was first flown in 2006 and designed along the lines of a reconnaissance UAV. The Desert Hawk III system is a dimensionally larger, lighter upgrade of the original Desert Hawk UAV appearing in the early 2000s. (Lockheed Martin)



The 7lb Desert Hawk III vehicle is powered by a single, low-signature electric motor driving a two-blade propeller unit fitted to the front of the fuselage. (Lockheed Martin)

GCS 103
GROUND CONTROL STATION
CAGE CODE
PART NO.
DESERT HAWK III

The Desert Hawk III is rather simply hand-launched by the operating crew to which control of the airborne is then managed through a briefcase-style ground control station. (Lockheed Martin)



Since the Desert Hawk III lacks a traditional wheeled undercarriage, it is recovered by way of a belly landing and also features an inherent "break apart" design, which allows for hard landings while preserving the critical components of the UAV. (Lockheed Martin)

A military drone technician secures the Lockheed Martin-developed Desert Hawk III after a field test. (Lockheed Martin)

P-175 POLECAT

2005

PROGRAM: P-175

Name: Polecat

Mission: Technology demonstrator

Length: 10ft (3.05m)

Wing Span: 90ft (27.43m)

Height: >4ft (1.2m)

Max T.O. Weight: 9,000lb (4,082kg)

First Flight: 2005

Last Flight: 18 December 2006

Crew: Unmanned

Number Built: 2

Power Plant: 2 x Williams FJ44-3E turbofans

Design Speed: Subsonic

Service Ceiling: 65,000ft (20,000m)

Combat Radius: N/A

Weapons Load: 1,000lb (450kg) sensors or weapons

Polecat was a Lockheed-funded research program that began in March 2003, with the flying-wing UAV flying secretly towards the end of 2005. The Lockheed Martin P-175 Polecat was a 9,000lb (4,100kg) flying wing, and it was designed to carry a payload. The bat-wing-shaped Polecat had a 90ft wing span, and it was designed to cruise at 65,000ft. It was powered by twin Williams FJ44-3E engines that generated 6,000lb of thrust and allowed it to carry up to 1,000lb in payload.

The one-of-a-kind, $27 million prototype was destroyed in a crash in December 2004 when a ground equipment failure triggered the platform's flight termination system. The company released a photograph of the Polecat high-altitude unmanned aerial demonstrator flying over "a remote desert location" on 19 July 2005.

The Polecat UAV was a blended wing-body aircraft that appears to be a miniaturized version of the B-2 Spirit stealth bomber. By early 2005 Lockheed Martin was considering building a replacement for its P-175 Polecat private-venture unmanned air vehicle demonstrator which had crashed. Nothing had been firmly decided, but it was certainly being discussed. Company officials say they did manage to validate some flight control and handling work with Polecat. On 19 July 2006 Lockheed Martin unveiled the existence of a new high-altitude, unmanned aerial demonstrator to reporters attending the Farnborough International Air Show. The announcement was part of a review of several Skunk Works projects highlighting technologies that the company was exploring to enable technology for the future.

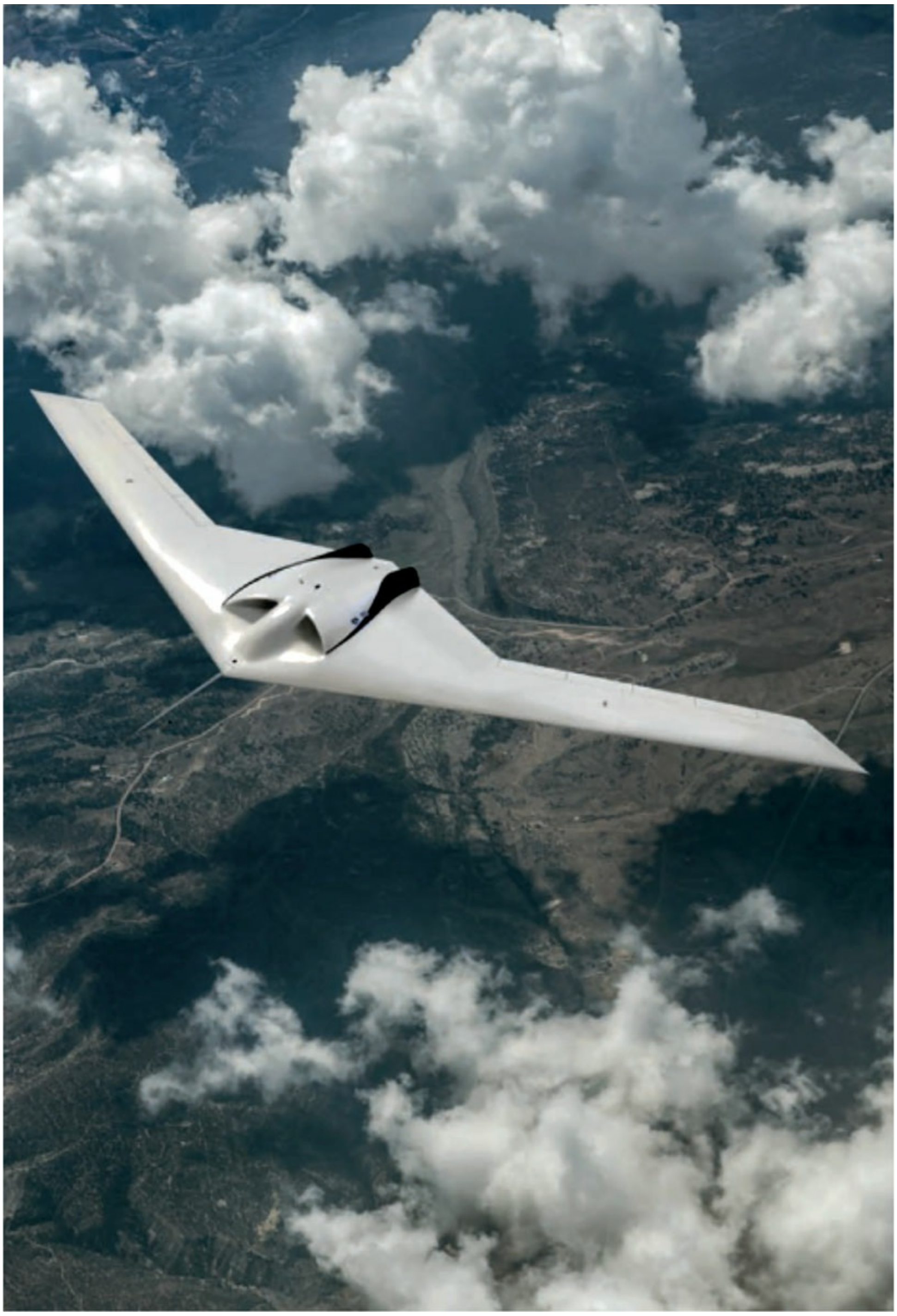
"This UAV was an effort to better understand the flight dynamics of a tailless unmanned air system in support of our ongoing research and development work for the USAF's future Long Range Strike Program as well as to field the next generation of structural composite concepts," explained Frank Cappuccio, then executive vice president and general manager of Advanced Development Projects and strategic planning.

The Polecat was specifically designed to verify three things:

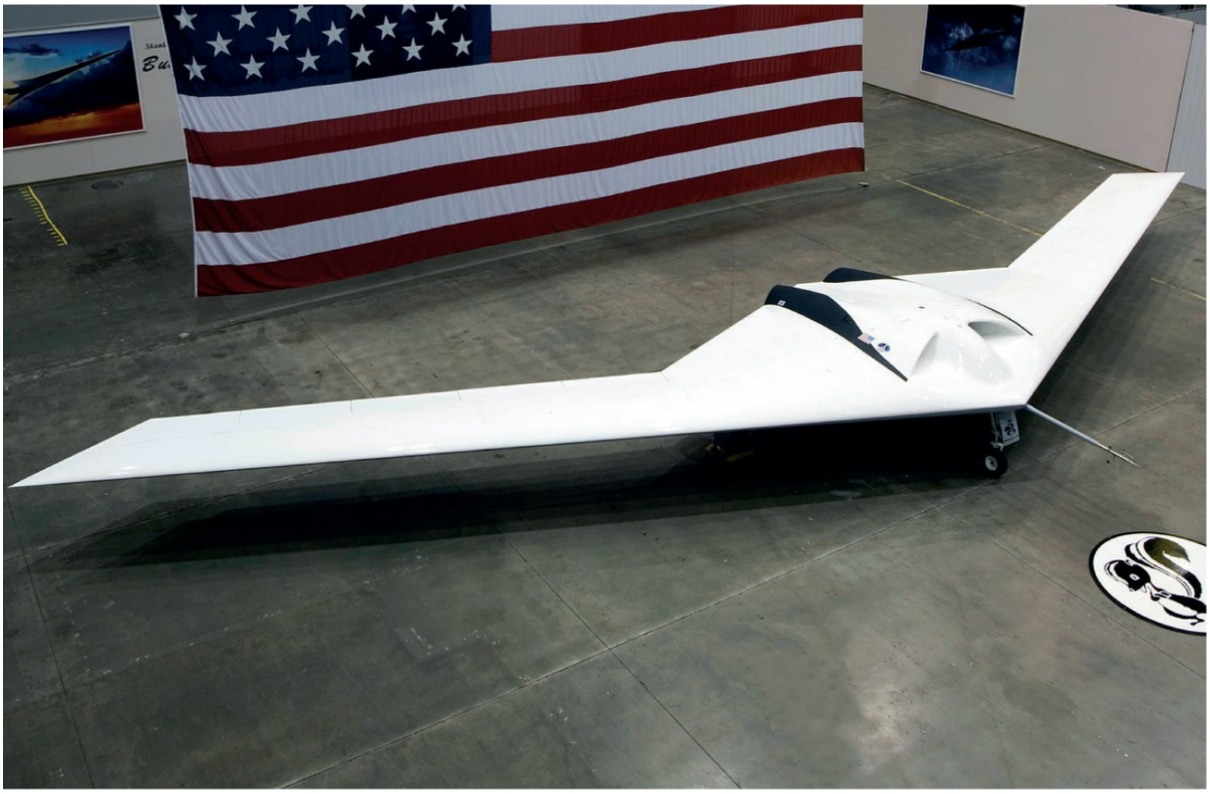
- Cost effective rapid prototyping and manufacturing techniques of composite materials.
- Projected aerodynamic performance required for sustained high-altitude operations.
- Fight autonomy attributes.

In addition, the company investment and the resulting successful flights were proof positive of Lockheed Martin's commitment to developing the next inflection point in unmanned systems. Frank Cappuccio said of the Polecat that it featured a:

> Tail-less flying-wing configuration, of advanced laminar flow aerofoil section, blending high aerodynamic efficiency with a very low radar cross-section. It is described as consisting of fewer than 200 parts, being of 98 percent bonded composites construction, and fabricated using a new, low-temperature manufacturing process. Normally, composites are autoclaved and cured in temperatures of 177°C (350°F), but in the case of the Polecat they were cured at only 66°C (150°F) and post-cured later. The wing is said to have been shaped for low-observables (LO), but not treated (coated) for LO. The aircraft has a fully retractable tricycle landing gear.



The Lockheed Martin Polecat was a private-venture high-altitude UAS flying wing development intended for data collection and research. Recording a first flight in 2005, the Polecat led a very short life as it crashed on 18 December 2006 when communication with the ground unit was lost. The project was terminated two days later. (Lockheed Martin)



The Polecat featured a wing span of 90ft and a gross weight of 9,000lb and a payload capacity for up to 1,000lb of internally held mission equipment. Power was through 2 x Williams FJ44-3E turbofan engines, each developing 3,010lb of thrust output. (Lockheed Martin)

The P-175 Polecat is being prepped for a move to Stall One for an engine run on 24

July 2006. (Lockheed Martin)

The nearly completed P-175 Polecat in Stall One at the Lockheed Martin Skunk Works at their Palmdale, CA, location. (Lockheed Martin)

Flight-test and ground crew move the Polecat into Stall One for an engine run on 24 July 2006. (Lockheed Martin)

Moving the P-175 to Stall One for its very first engine run. (Lockheed Martin)

P-175 Polecat during its flight on 19 June 2005. (Lockheed Martin)

CORMORANT

2006

PROGRAM: Cormorant

Name: Surface and Underwater Launch and Recoverable UAV

Mission: Submarine launch UAV

Length: 17ft (5.18m)

Wing Span: 7ft (2.1m) with wings folded; 17ft (5.18m) for flight

Height: 5ft 6in (1.65m)

Max T.O. Weight: 4,000lb (1,814.4kg)

First Flight: Not flown (prototype was tested and fit into the launch tube of an Ohio class SSBN)

Last Flight: N/A

Crew: Unmanned

Number Built: 1

Power Plant: 1 x Teledyne CAE J402-CA-400

Design Speed: Subsonic

Service Ceiling: Below 28,000ft (8,534.4m)

Combat Radius: Less than 150 miles (130nm; 241km)

Weapons Load: N/A

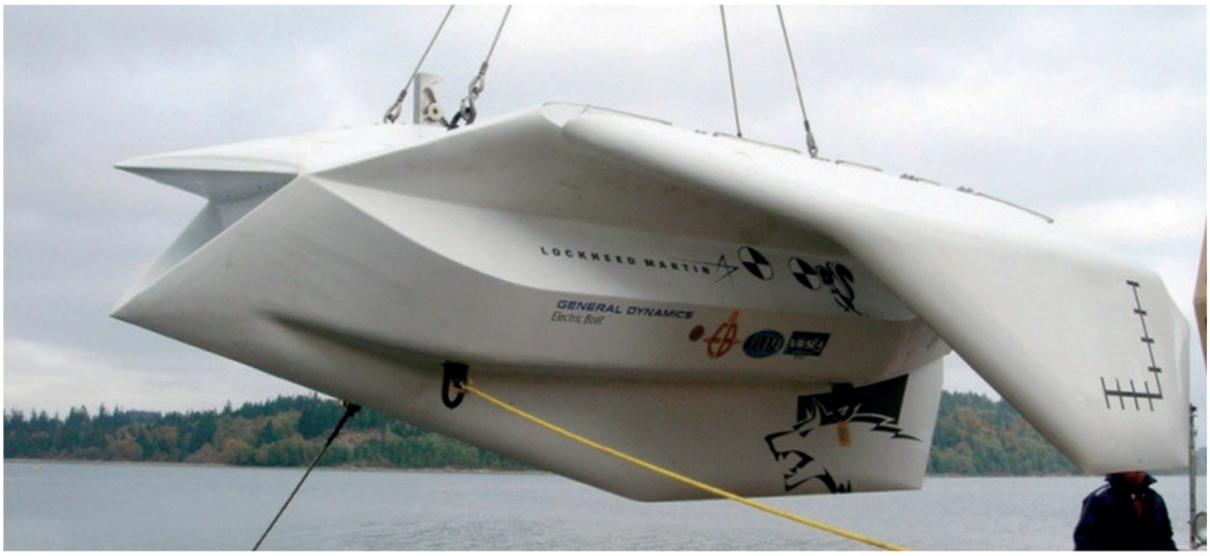
With the Cormorant, Lockheed Martin's Skunk Works, famed for spy planes that flew higher than anything else in the world in their day, was trying for a different altitude record: an airplane that started and ended its mission 150ft under water. The Cormorant was a stealthy, jet-powered, autonomous aircraft that could be outfitted with either short-range weapons or surveillance equipment, and designed to launch out of the Trident missile tubes in some of the US Navy's gigantic Cold War era Ohio-class submarines. These formerly nuke-carrying subs have become less useful in a military climate evolved to favor surgical strikes over nuclear stalemates, but the Cormorant was designed to use their now-vacant tubes to provide another unmanned option for spying on or destroying targets near the coast.

This is no easy task. The tubes are as long as a semitrailer but about 7ft wide, not exactly airplane-shaped. The Cormorant had to be strong enough to withstand the pressure 150ft under water – enough to cave in hatches on a normal aircraft – but light enough to fly. Another challenge: subs survive by stealth, and an airplane flying back to the boat could give its position away.

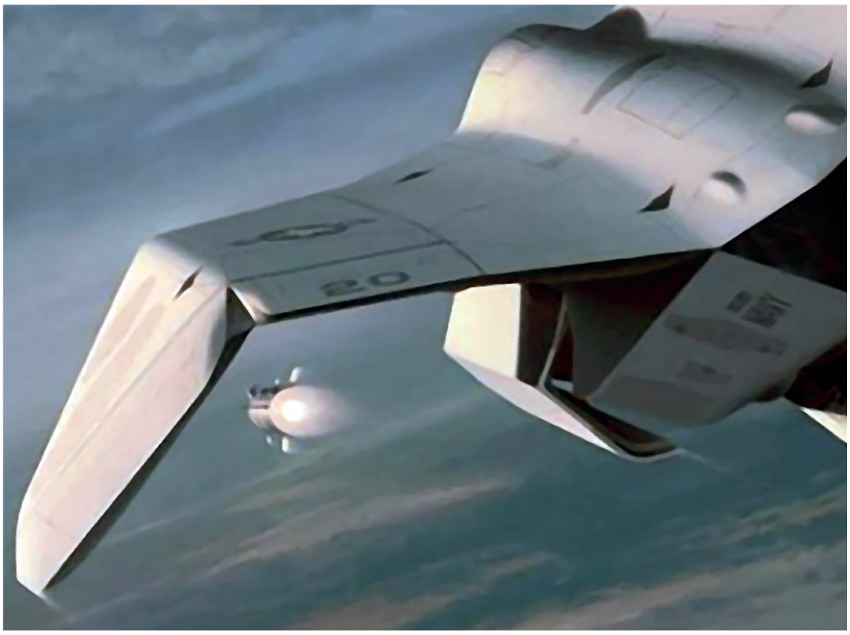
The Skunk Works' answer was a 4-ton airplane with gull wings that hinged around its body to fit inside the missile tube. The craft was made of titanium to resist corrosion, and any empty spaces were filled with plastic foam to resist crushing. The rest of the body was pressurized with inert gas. Inflatable seals kept the weapon-bay doors, engine inlet and exhaust covers watertight.

The Cormorant did not shoot out of its tube like a missile. Instead an arm-like docking "saddle" guided the craft out, sending it floating to the surface while the sub slipped away. As the drone popped out of the water, the rocket boosters fired and the Cormorant took off. After completing its mission, the plane flew to the rendezvous coordinates it received from the sub and landed in the sea. The sub then launched a robotic underwater vehicle to fetch the floating drone. DARPA funded the tests of some of the Cormorant's unique systems, including a splashdown model and an underwater-recovery vehicle.

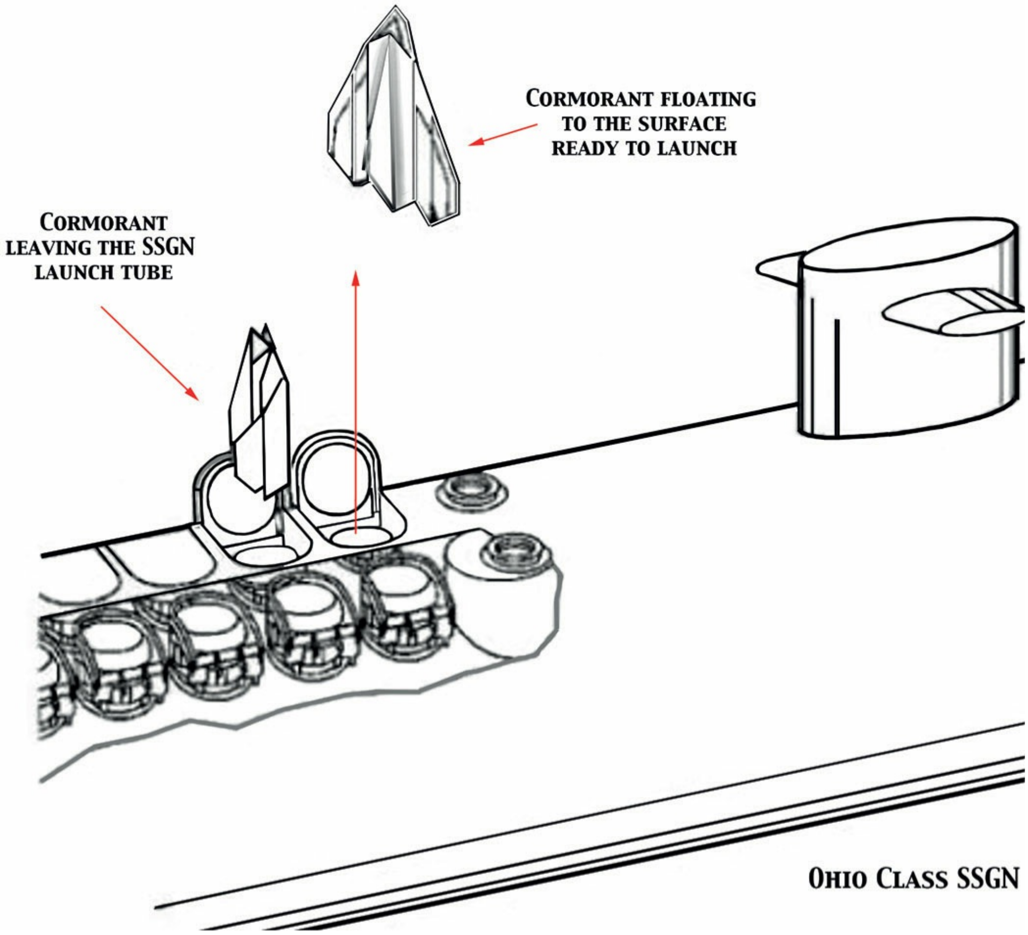
Although the Cormorant achieved its goals and provided the required capabilities during tests, DARPA canceled the contract due to budget cuts in 2008.


LOCKHEED MARTIN
GENERAL DYNAMICS
Electric Boat

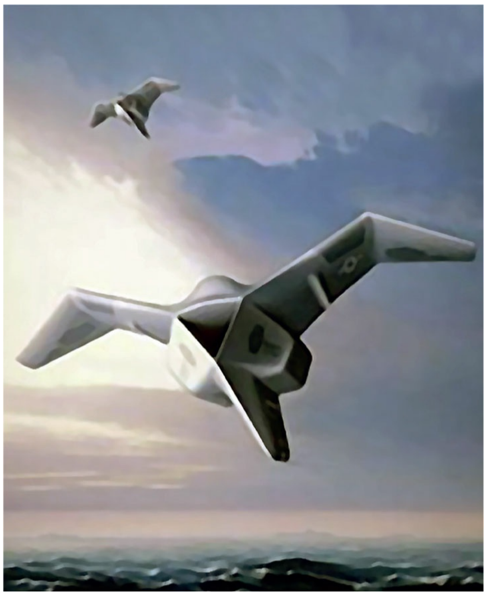
Cormorant was Lockheed Martin Skunk Works' concept for a submarine-launched unmanned air vehicle. The design was a response to the DARPA multi-purpose unmanned air vehicle (MPUAV) program, which began in 2006. (Lockheed Martin)



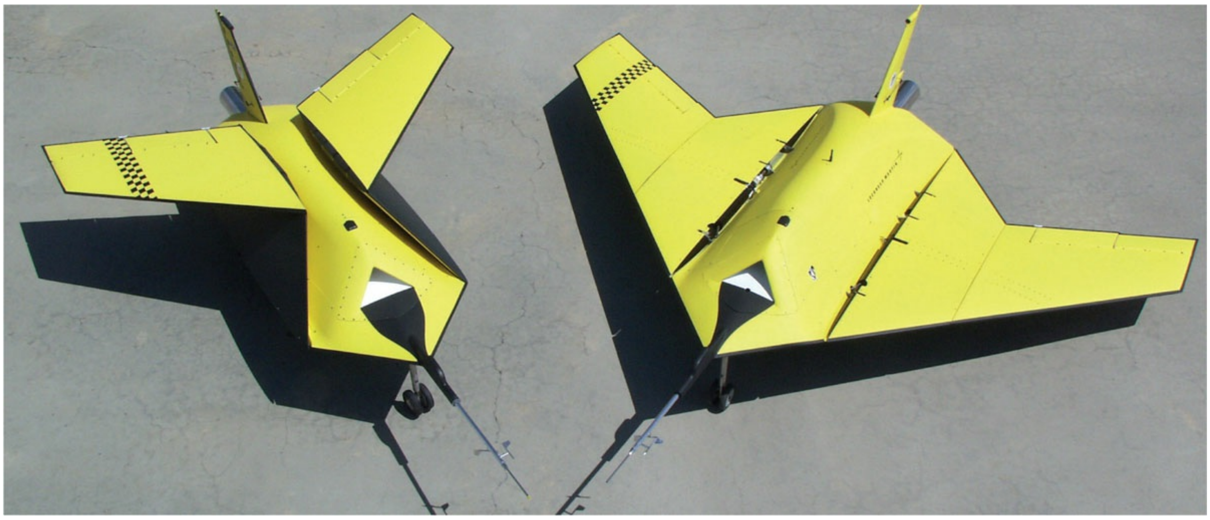
A Lockheed Martin illustration of what the Cormorant could do, such as carrying weapons, a reconnaissance package or intelligence-gathering equipment/sensors. (Lockheed Martin)


CORMORANT FLOATING
TO THE SURFACE
READY TO LAUNCH
CORMORANT
LEAVING THE SSGN
LAUNCH TUBE
OHIO CLASS SSGN

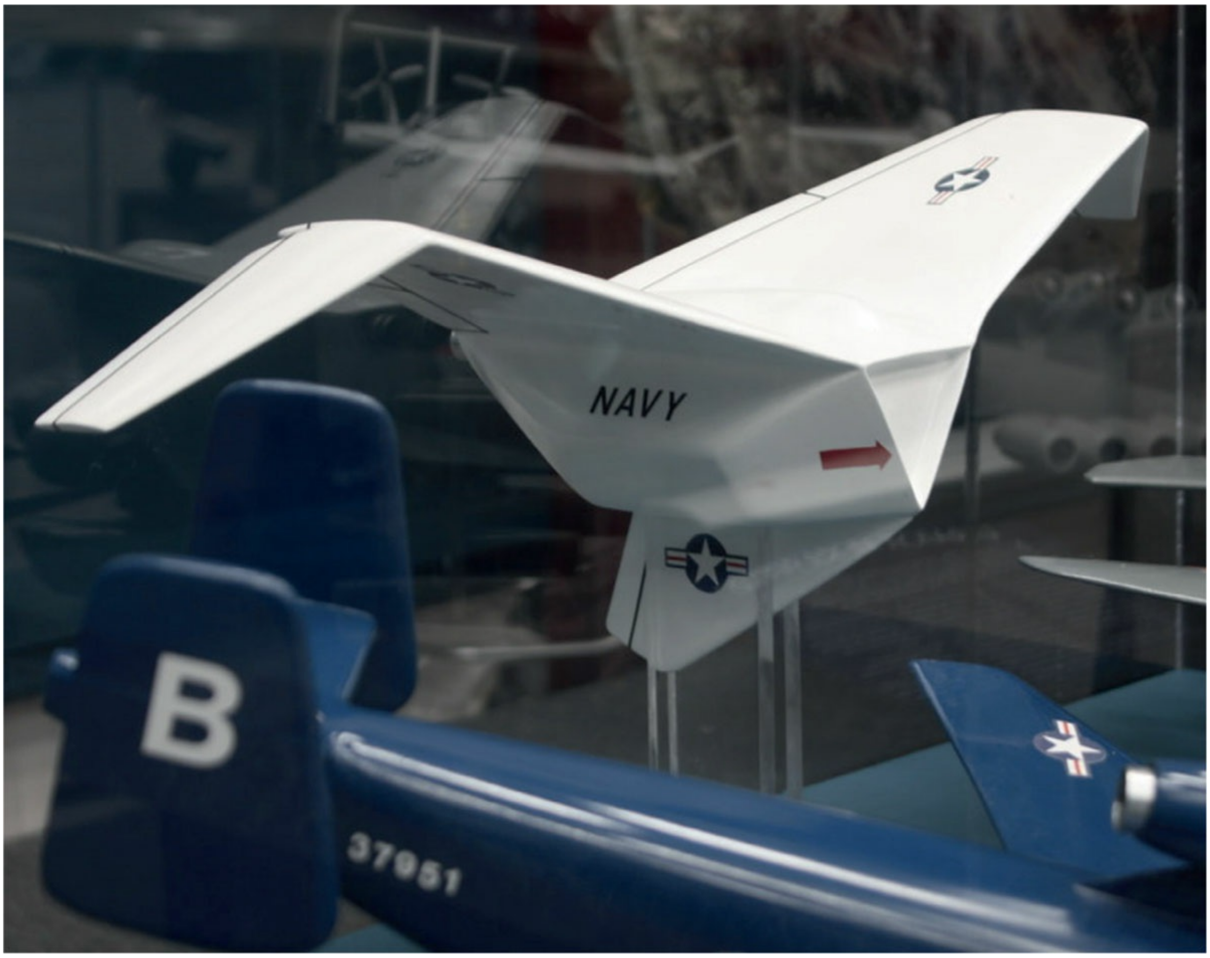
The 17ft-long jet-powered stealthy UAV would be launched from the missile tube of the Navy's four converted ballistic missile submarines (SSGNs), propelled into the air by rocket boosters, recovered into the water by parachute, then pulled back into the submarine with a remotely operated vehicle. (Lockheed Martin)



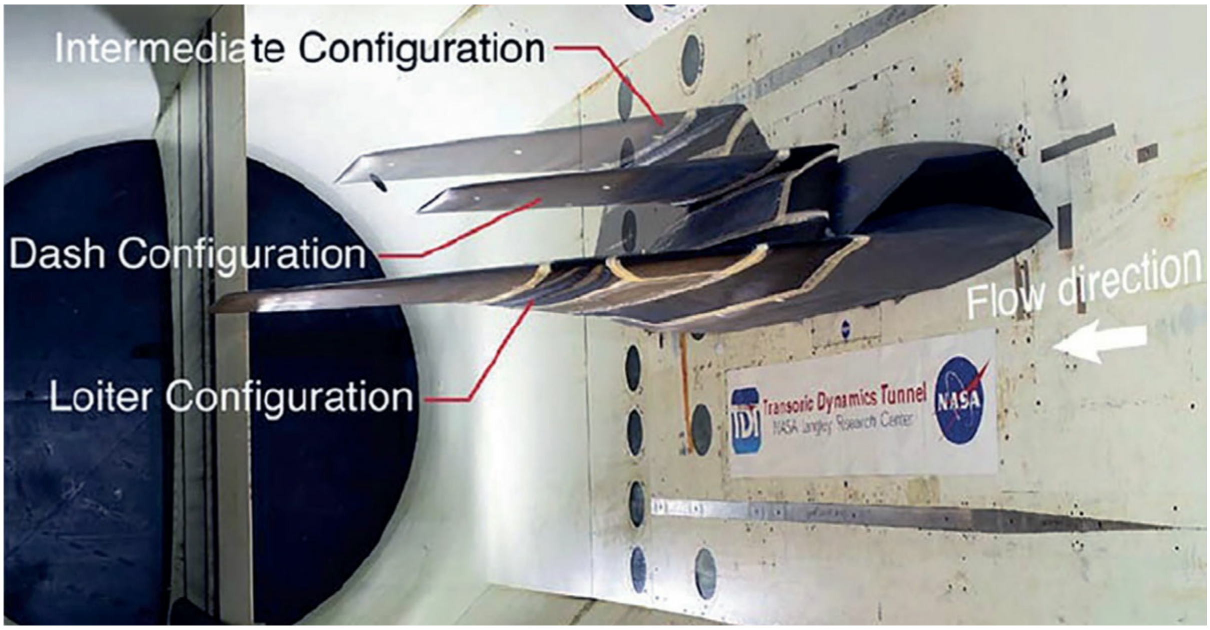
An illustration of a pair of Cormorants in flight. (Lockheed Martin)

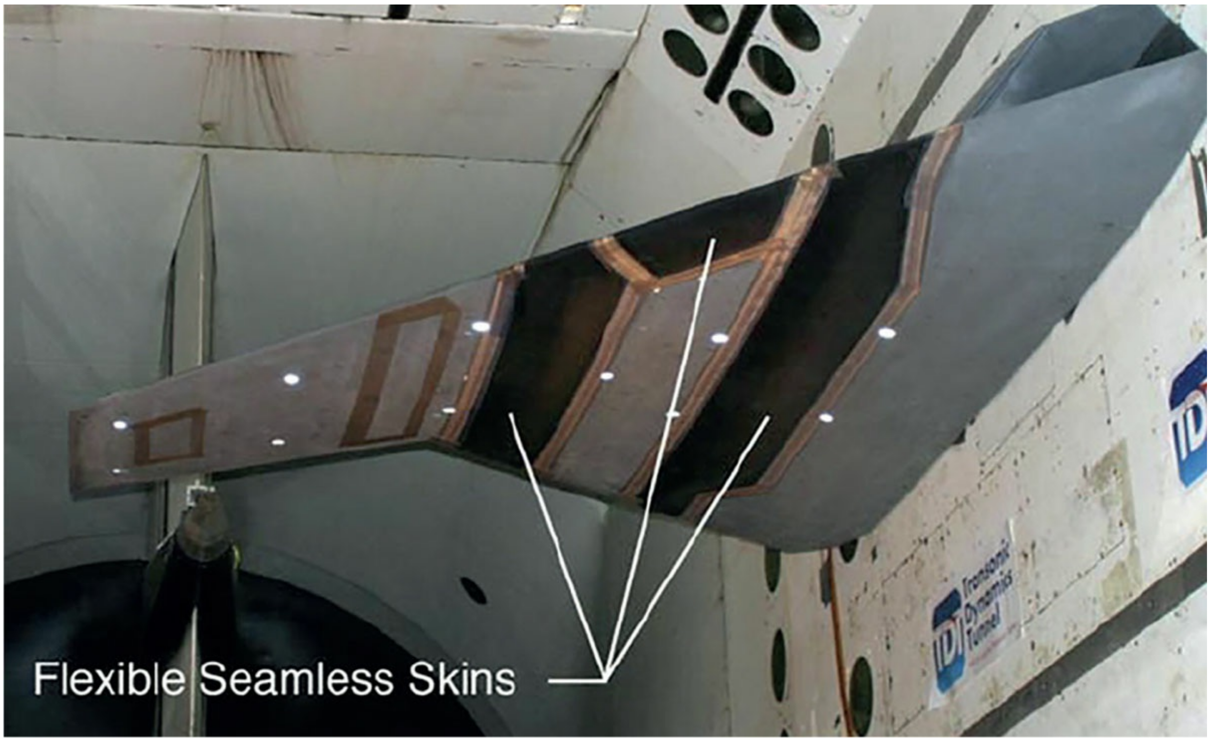


An artist’s rendering showing how the Cormorant wing/body would fold to fit into the launch tube of an Ohio-class SSGN arsenal boat. (Lockheed Martin)

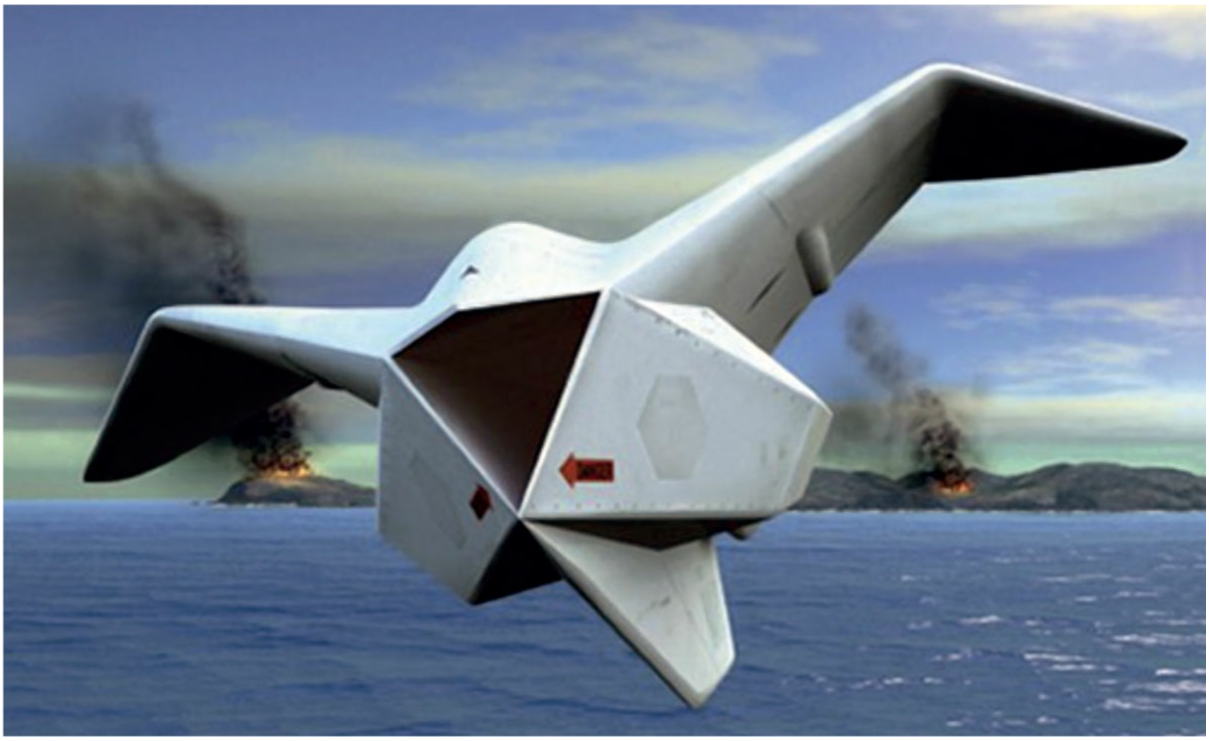

NAVY
B
37951

A one-tenth-scale model of the Cormorant. (Author's collection)


Intermediate Configuration
Dash Configuration
Loiter Configuration
Flow direction
TDT Transonic Dynamics Tunnel
NASA Langley Research Center
NASA

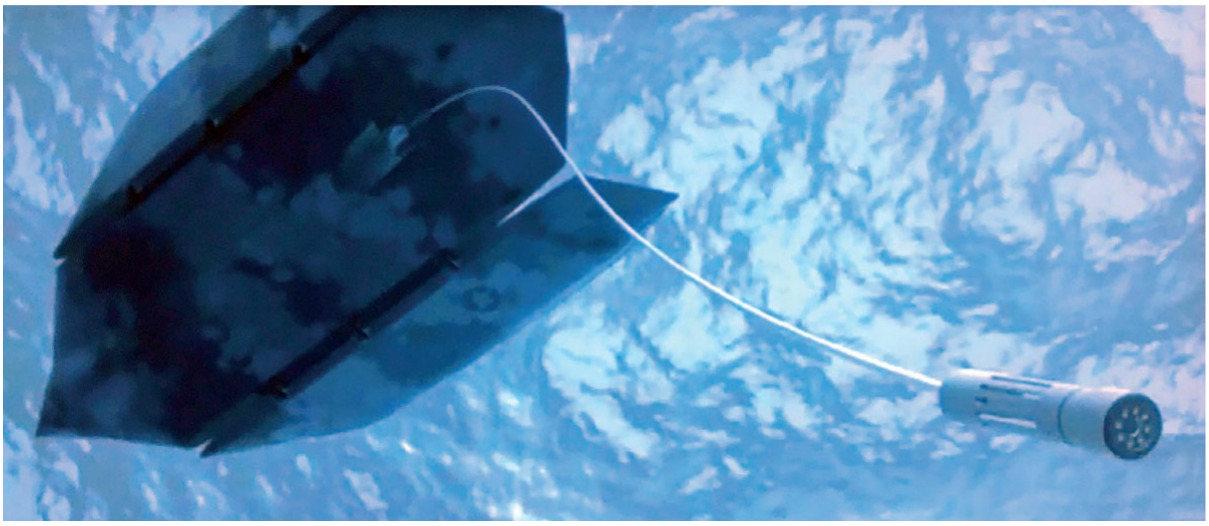

Flexible Seamless Skins
TDT Transonic Dynamics Tunnel

In a NASA wind tunnel, the folding wings go through their paces to ensure that the wings and seals function over repeated uses. (Lockheed Martin)



An illustration showing a Cormorant in flight heading to monitor an adversary's activities before turning to be recovered by an Ohio-class SSGN. (Lockheed Martin)

This image was taken from a Lockheed Martin YouTube video illustrating how the Cormorant would be launched form an Ohio-class SSGN. (Lockheed Martin)



Once the Cormorant has completed its mission, it would land in the water and wait for a recovery submarine to find the recovery cable and haul it back in the launch tube. (Lockheed Martin)

P-791

2006

PROGRAM: P-791

Name: LMH-1

Mission: Hybrid cargo airship

Length: 280ft (85.37m)

Wing Span: 148ft (45.11m)

Height: 77.99ft (23.77m)

Max T.O. Weight: N/A

First Flight: 31 January 2006

Last Flight: Still in flight-test

Crew: 3

Number Built: 1

Power Plant: 4 x V6 diesel-fueled engines driving three-bladed propellers

Design Speed: Mach 0.09 (69mph; 111km/h)

Service Ceiling: >18,000ft (5,486m)

Combat Radius: 1,616 miles (1,404nm; 2,600km)

Weapons Load: Up to 47,000lb (21,319kg) of cargo or 19 passengers

Hybrid airships make it possible to affordably deliver heavy cargo and personnel to remote locations around the world. Burning less than one-tenth the fuel of a helicopter per ton, the hybrid airship will redefine sustainability for the future.

With unlimited access to isolated locations around the globe, hybrid airships safely and sustainably support a wide range of activities in areas with little to no infrastructure. The airship offers the simplicity of a pickup truck by carrying cargo loads and personnel in and out of remote areas daily, not just in certain seasons or only after major road, rail or airport infrastructure is developed.

Lockheed Martin has invested more than 20 years to develop the hybrid airship's technology, prove its performance and ensure there are compelling economics for various markets which would benefit from using this platform. More than ten years ago, the team built and flew the technology demonstrator known as the P-791, which successfully demonstrated all the technologies needed to make this real. Since then, the team has completed all required FAA certification planning steps for a new class of aircraft and it is ready to begin construction of the first commercial model and the completion of the FAA Type certification process.

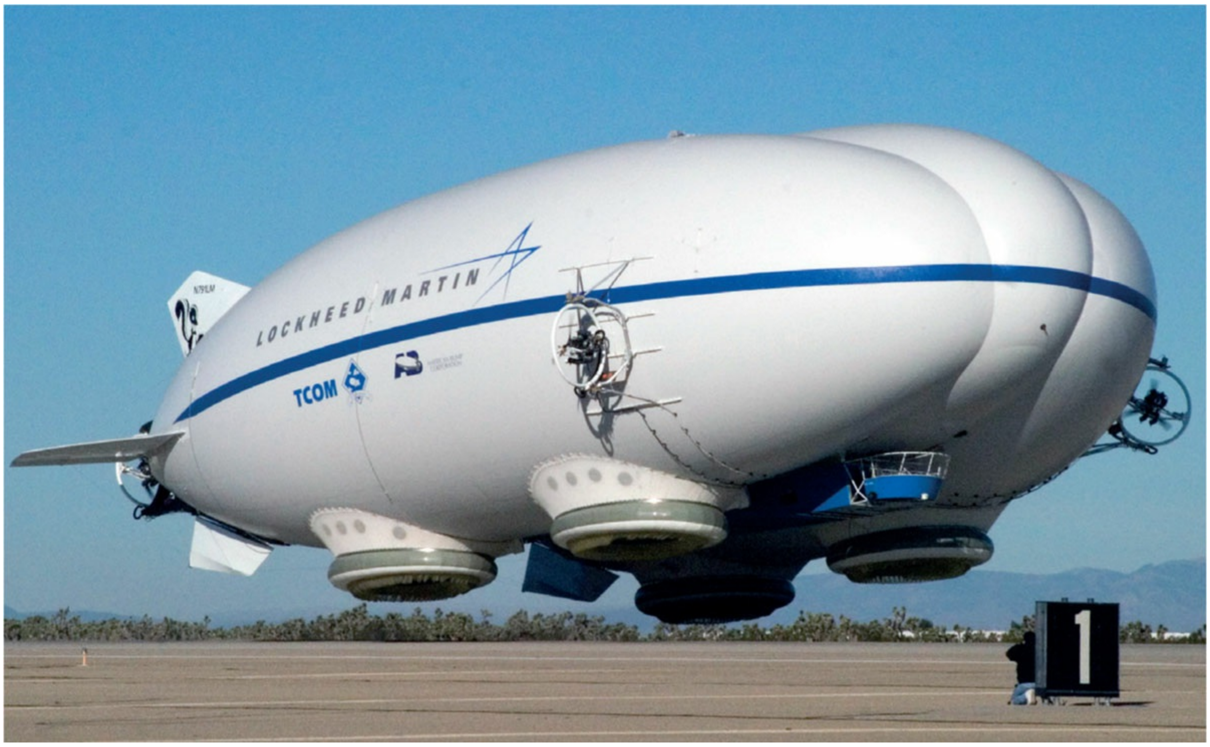
More than two-thirds of the world's land area and more than half of the world's population do not have direct access to paved roads or runways. This lack of infrastructure presents numerous challenges for worldwide humanitarian relief, natural resource extraction and heavy cargo operations. In most cases, developing these areas to accommodate roads or airways is not an option, so for centuries they've remained isolated. To combat these challenges, the Skunk Works team developed a one-of-kind hybrid airship that offers large cargo capacity with significant reductions in fuel consumption compared to other air vehicles, all the while remaining faster than land and sea transportation systems.

What is a hovercraft? It is part boat, part airplane and part helicopter. While it may look a bit odd, how it works is quite simple. It's an amphibious vehicle that travels on a cushion of air created by a downward blast. Hovercraft use air to balance their weight, allowing the craft to operate efficiently. Hovercraft can also operate across nearly any terrain, including land, water and ice. It is this characteristic that makes hovercraft technology the ideal match for the hybrid airship, the cargo-hauling ship of the skies, enabling the airship to access remote locations around the world.

From carrying heavy equipment to isolated regions of Alaska, to serving as a flying clinic for disaster-relief efforts, there is almost no cargo mission this ship can't perform. This is due to the fact that the airship can land nearly anywhere. One of the biggest challenges to traditional cargo airship operations is how and where you park the airship. It is very expensive and time consuming to develop infrastructure in remote areas around the world. The ACLS allows the hybrid airship to access these isolated regions without needing to build any runway or roads.

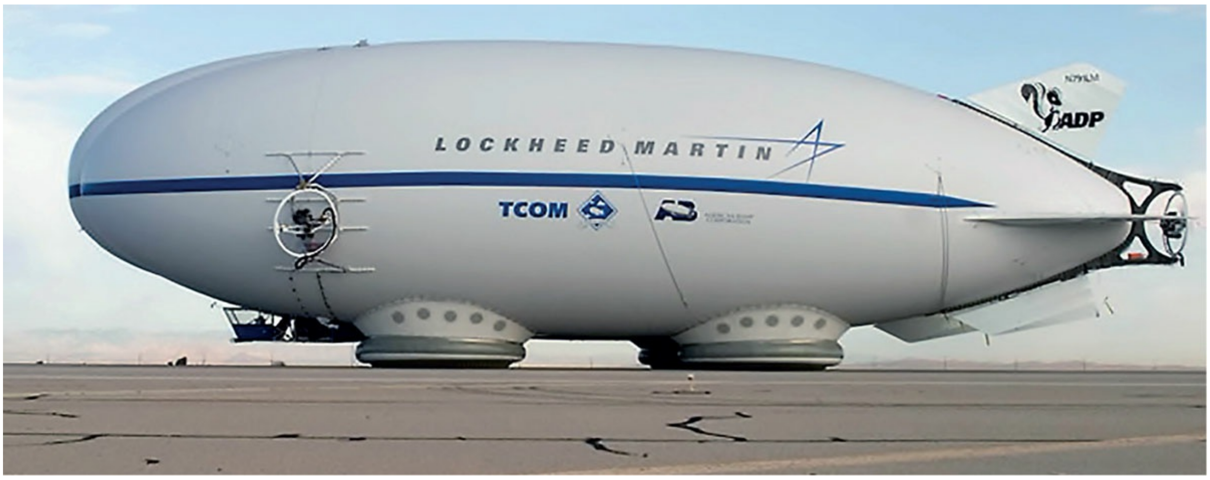
What gives the hybrid airship this capability? The air cushion landing system (ACLS) looks like giant inflatable doughnuts on the bottom of a large blimp, and it makes the challenge of accessing remote regions around the globe a thing of the past. Lockheed Martin Skunk Works developed an ACLS that blends hovercraft technology with its airship design. The ACLS system consists of three underbody hover pads. These hover pads create a cushion of air that allows the airship to float along the ground nearly friction free. The system gives the hybrid airship a unique capability to hover over water, a capability unmatched by any other cargo-hauling air vehicle.

If the hybrid airship needs to park on land, that's not a problem either. As the airship taxis, the hover pads "grip" to the ground with light suction pressure to keep the airship from moving in variable winds. "Fingers" hang below the pads to create a seal with the ground. These fingers allow the airship to taxi over obstacles, such as tree stumps or rocks, so extensive site preparation is not needed for a high-volume cargo operation. These fingers also make the hovercraft a sustainable solution because there is no long-term impact to the ground site. With this innovative system, the hybrid airship is able to travel virtually anywhere and affordably stay there.

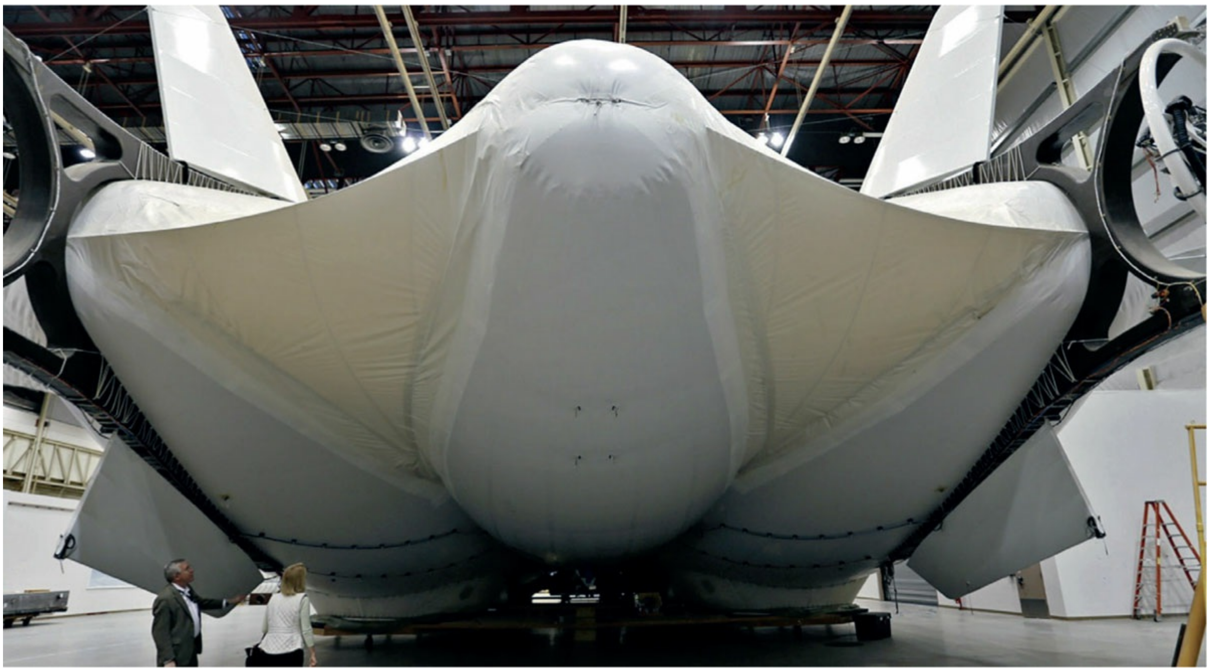


The Lockheed Martin P-791 hybrid airship served as the basis for the design of a larger airship intended for the US Army. It is shown here lifting off the runway at Air Force Plant 42, Palmdale. (Lockheed Martin)

The P-791 awaits the media on the day of its public showing. (Lockheed Martin)


LOCKHEED MARTIN
TCOM
ADP
N791LM

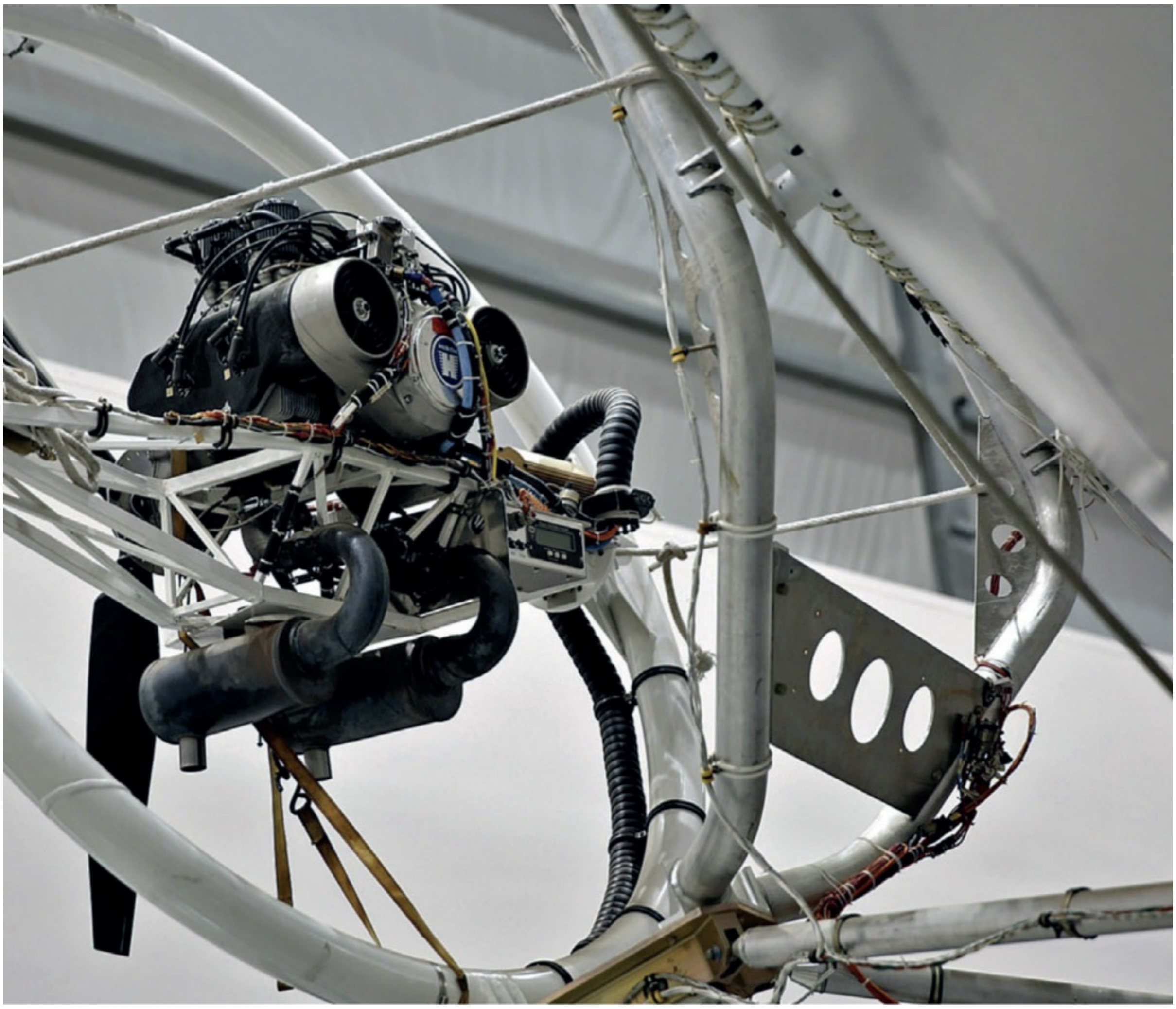
A new generation of high-tech airships can go where roads currently can't in places such as northern Canada, western China and Africa. (Lockheed Martin/LA Times)



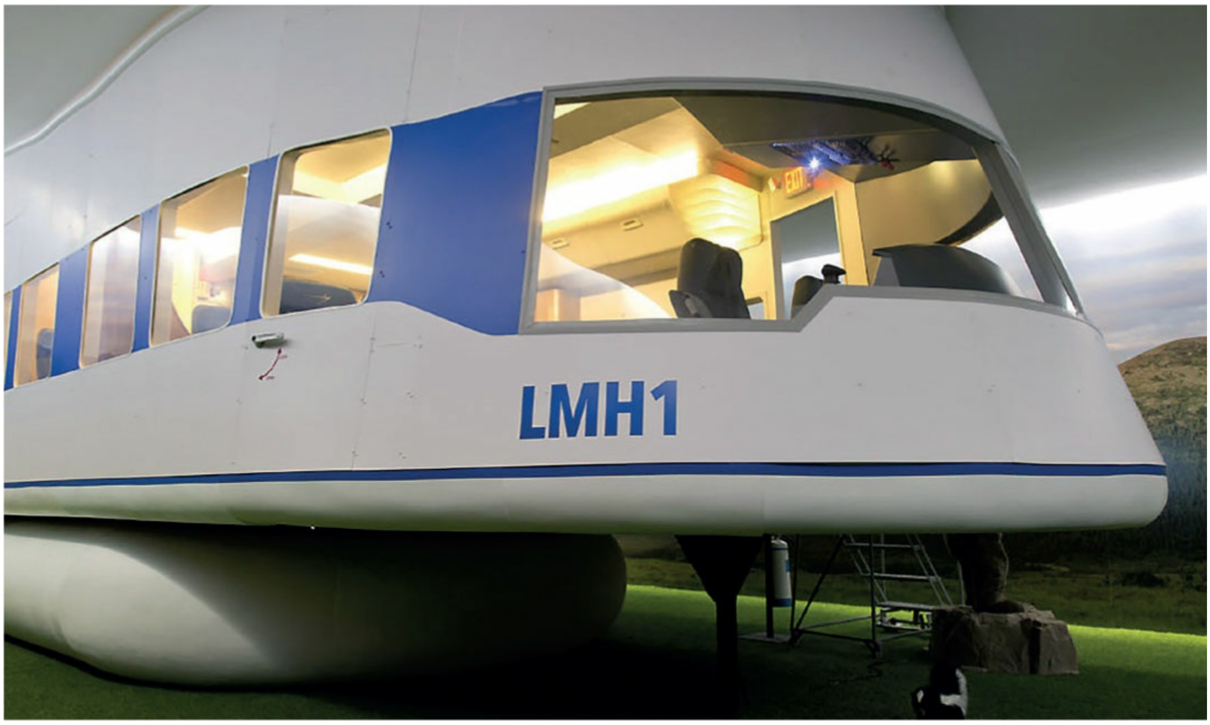
The view of the P-791 showing the position of the rear thrusts and the tri-hull layout of the P-791. (Lockheed Martin/LA Times)

N791LM
LOCKHEED MA
TCOM

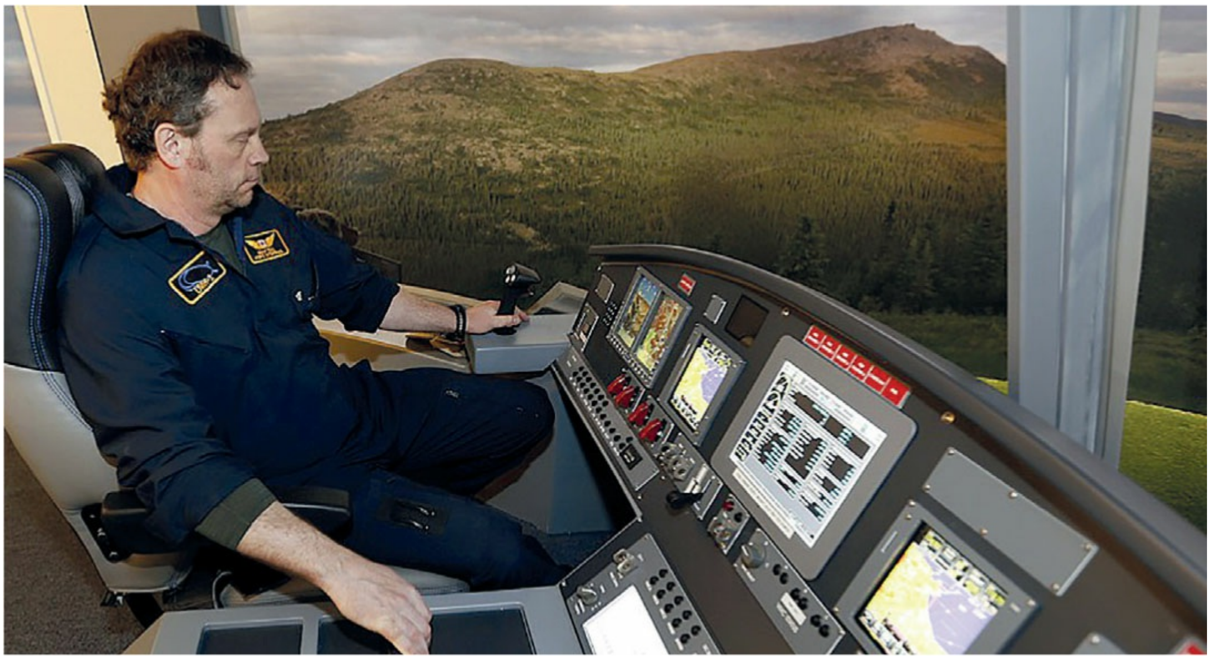
The media is given a tour of the P-791 at Lockheed Martin's Palmdale facility. (Lockheed Martin/LA Times)



A detailed closeup of the one of the four gimbled thrusters. They can go 360 degrees in all axes. (Lockheed Martin/LA Times)



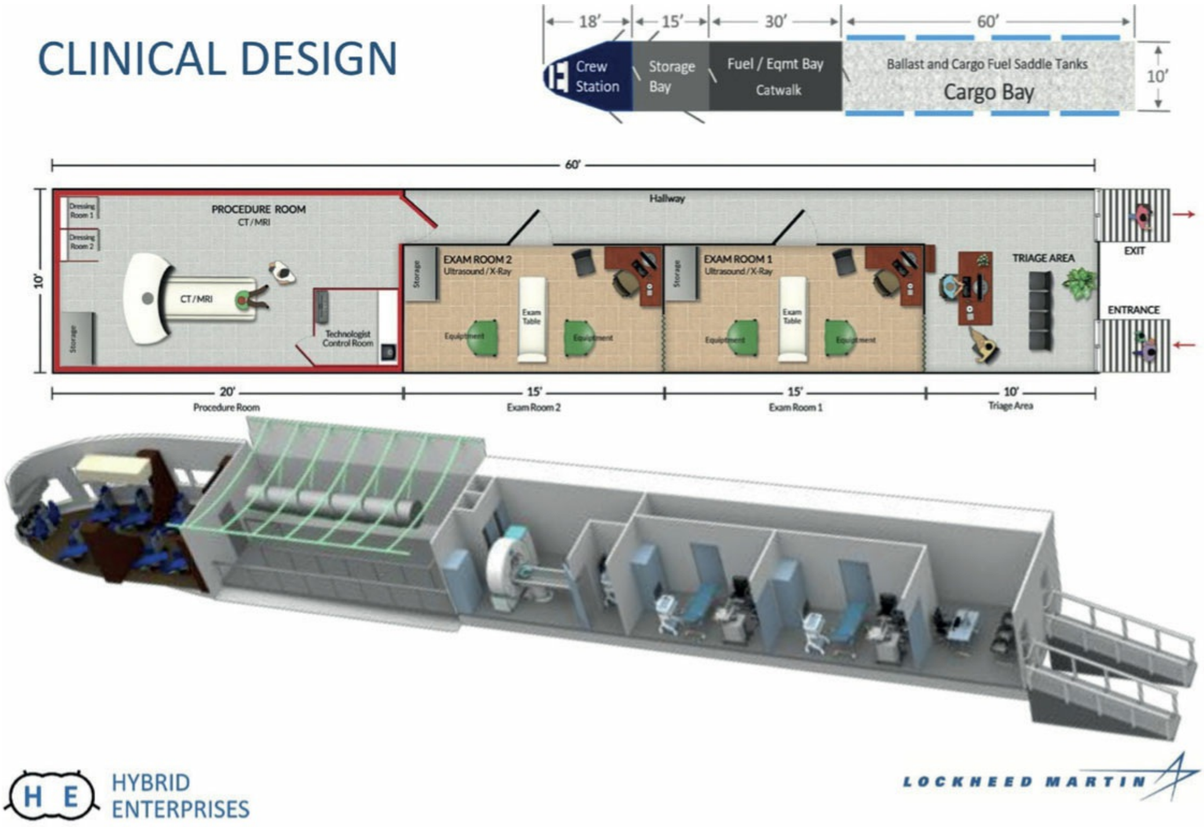
The passenger/crew module on the P-791 has a windscreen tilted inward to avoid or minimize glare. (Lockheed Martin)



The all-glass cockpit controls the P-791's flight via thrust vectoring and the four control surfaces via a fly-by-wire. The full axis flight control system controls the tails, the four gimballed thrusters, the throttles and the blade pitch. (Lockheed Martin)

Due to the limited cabin layout seating density, the LMH-1 is very spacious by today's aviation standards. (Lockheed Martin)

The layout of the cabin in the P-791 is limited to 19 seats, which is the largest passenger load that doesn't require a cabin attendant. (Lockheed Martin)


CLINICAL DESIGN
18′
15′
30′
60′
Crew Station
Storage Bay
Fuel / Eqmt Bay
Catwalk
Ballast and Cargo Fuel Saddle Tanks
Cargo Bay
10′
60′
10′
Dressing Room 1
Dressing Room 2
PROCEDURE ROOM
CT / MRI
CT / MRI
Storage
Technologist Control Room
Hallway
EXAM ROOM 2
Ultrasound / X-Ray
Storage
Exam Table
Equipment
Equipment
EXAM ROOM 1
Ultrasound / X-Ray
Storage
Exam Table
Equipment
Equipment
TRIAGE AREA
EXIT
ENTRANCE
20′
Procedure Room
15′
Exam Room 2
15′
Exam Room 1
10′
Triage Area
HYBRID ENTERPRISES
LOCKHEED MARTIN

Some design ideas for the very large P-791's gondola and how it can be used for cargo, VIP transport, flying hospital or just passenger accommodation. (Lockheed Martin)

RQ-170 SENTINEL

2007

PROGRAM: RQ-170

Name: Sentinel/Beast of Kandahar

Mission: Strategic Reconnaissance

Length: 14ft 9in (4.5m)

Wing Span: 90ft (27.43m)

Height: 6ft (1.8m)

Max T.O. Weight: Unknown

First Flight: 1 September 2005

Last Flight: Still operational

Crew: Unmanned – 3 ground crew

Number Built: 20+ (still very classified)

Power Plant: 1 x General Electric TF34

Design Speed: Subsonic

Service Ceiling: 50,000ft (15,000m) estimated

Combat Radius: Classified

Weapons Load: Optical and electronic surveillance

The RQ-170 Sentinel is a high-altitude long-endurance UAV designed and manufactured by Skunk Works for the USAF.

The RQ-170 Sentinel UAV can capture real-time imagery of the battlefield and transfer the data to the ground control station (GCS) through a line of sight (LOS) communication data link. The vehicle was deployed to Afghanistan for Operation Enduring Freedom. It is also known as the Beast of Kandahar. Flying at an altitude of 50,000ft, the RQ-170 can offer its operators real-time intelligence data by executing surveillance and reconnaissance operations over a large area.

432nd Wing of Air Combat Command (ACC) at Creech AFB, Nevada, and 30th Reconnaissance Squadron at Tonopah Test Range are operating the Sentinel. The tailless flying wing design of the RQ-170 looks similar to the RQ-3 DarkStar and P-175 Polecat. The low-observable design enables the aircraft to fly on the borders of Iran, China, India and Pakistan for capturing real-time information regarding missile tests, telemetry and multi-spectral intelligence.

The development of the RQ-170 was started by Skunk Works to meet the stealth UAV demands of the USAF. The aircraft was designed to execute intelligence, surveillance, reconnaissance and target acquisition (ISTAR) and electronic warfare missions over a target area. The RQ (R stands for reconnaissance) designation indicates that the aircraft is unarmed.

The RQ-170 took off for its first flight secretly from Kandahar AFB in Afghanistan in 2005. The USAF officially unveiled the operations of RQ-170 in its fleet in December 2009. A South Korean newspaper, *Joong Ang Daily*, reported in December 2009 that the RQ-170 was flight-tested in South Korea to supersede the U-2 aircraft at Osan Air Base (AB) for carrying out missions over North Korea. It was redeployed to Afghanistan with the video-capturing feature in August 2010.

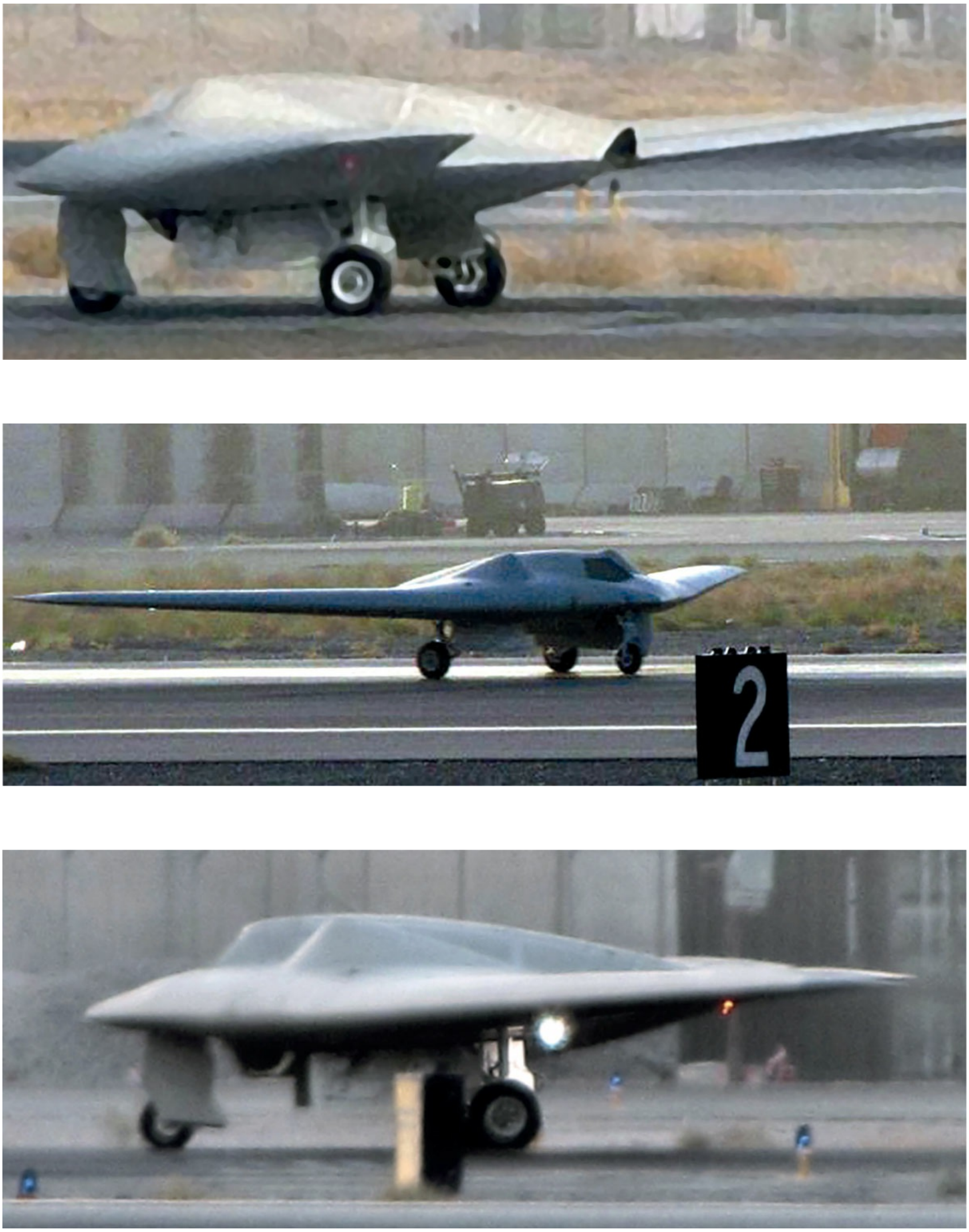
The Sentinel features bat-shaped wings, blended fuselage, pointed nose and tricycle-type landing gear. An electro-optic camera was incorporated beneath the front fuselage section to seize the real-time imagery or videos of the battlefield it is surveying. A direction satellite communication antenna enables communication between the vehicle and control station. About 90 percent of the aircraft is made up of composite materials to decrease its overall weight.

The RQ-170 can be controlled either manually from the GCS or through autonomous mode. An automatic launch and recovery (ALR) system facilitates the safe landing of the aircraft when communication with the control station fails.

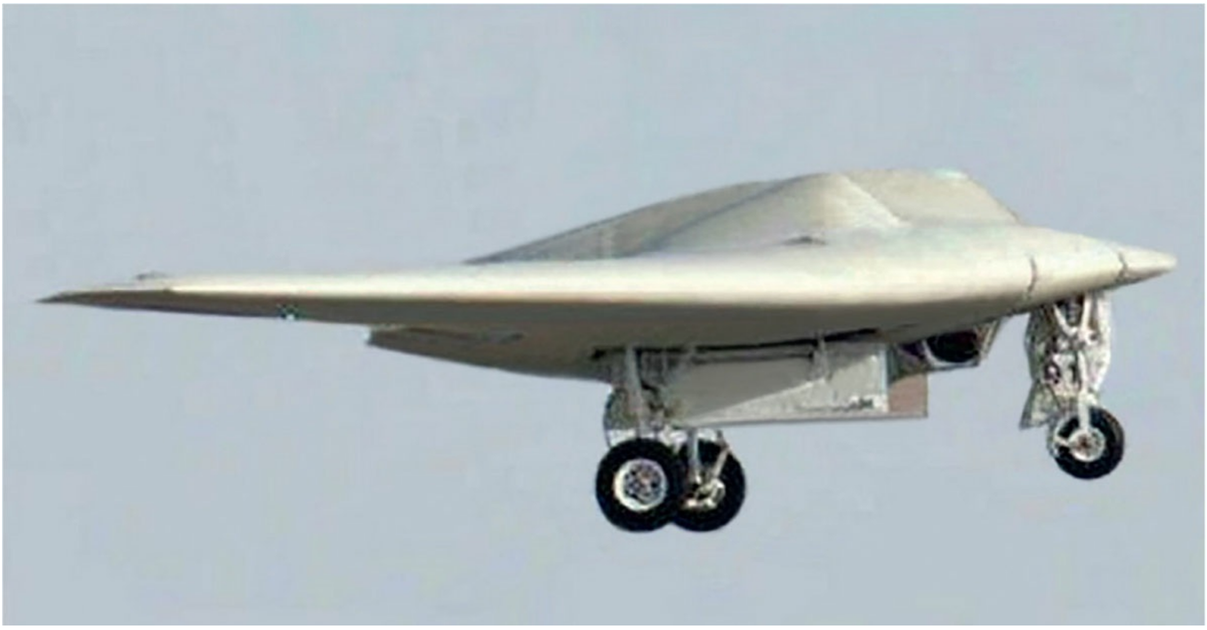
The RQ-170 Sentinel is fitted with an active electronically scanned array radar, synthetic aperture radar and signal intelligence in its belly fairings. It is powered by a single General Electric TF34 turbofan engine, which produces 9,275lb of thrust. The TF34 is designed and built by General Electric. It generates high thrust to weight ratio, consumes less fuel than other comparable engines and minimizes operational cost. The TF34 boasts dual-stage high-pressure turbines, four stage low-pressure turbines, an annular combustor engine configuration and 14-stage high-pressure axial flow compressors. The ground control station (GCS) of the RQ-170 displays the real-time imagery or videos captured by the vehicle's payload cameras onboard. The data supplied by the vehicle is retrieved, processed, stored and monitored at the control station, which was designed and built by Skunk Works. The GCS tracks, controls and monitors the RQ-170 by transferring commands to the vehicle via LOS SATCOM data link.

On 5 December 2011, a Lockheed Martin RQ-170 Sentinel UAV was captured by Iranian forces near the city of Kashmar, in northeastern Iran. The US government initially denied the claims but later President Obama acknowledged that the downed aircraft was a US drone.

The loss of the stealth drone was very significant. The RQ-170s are still pretty rare technology-wise, and to have one in such good condition to be lost to a potential adversary like this was pretty significant, especially because Iran has open ties to Russia and has been courted by China. A senior Lockheed Martin engineer told the author that most of the secret technology was housed in the bottom canoe, and when it belly landed, those components were destroyed.

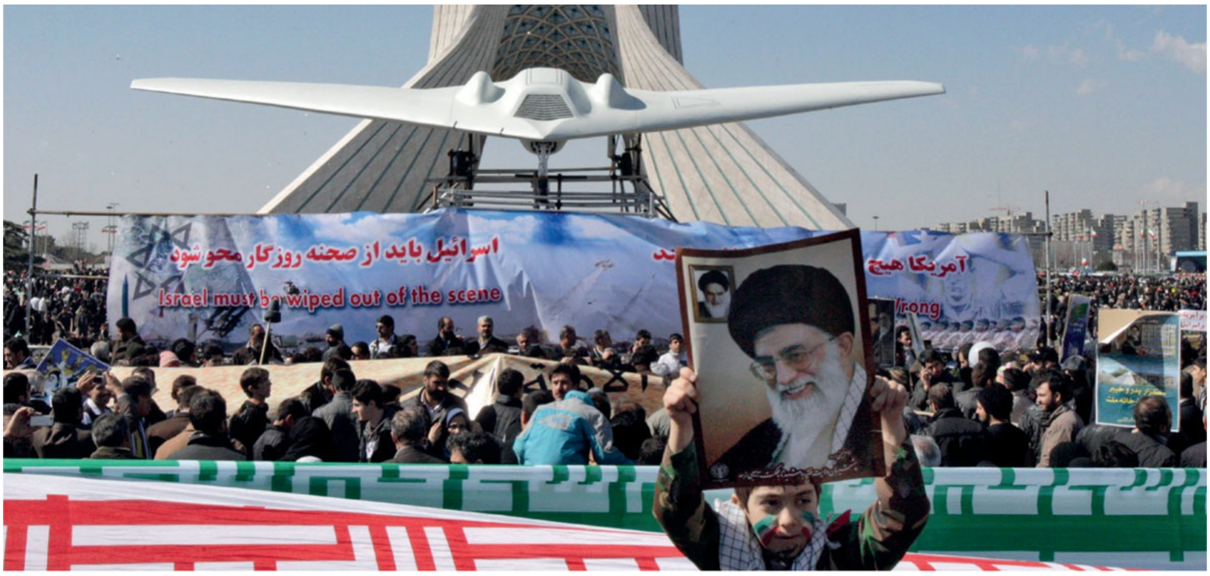


The “Beast of Kandahar” is captured landing at the Kandahar Air Base, Afghanistan, in early 2009. (Author’s collection)



A ground view of the RQ-170 Sentinel on a landing approach to Tonopah Test Range about 200 miles NNW of Las Vegas, NV. For over a decade since the "Beast of Kandahar" was first exposed, the RQ-170 has remained an elusive beast indeed. It's only known of it operating from six locales with certainty: Kandahar Airfield in Afghanistan, Kunsan Air Base, in South Korea, Andersen Air Force Base in Guam, Tonopah Test Range and Creech Air Force Base, NV, as well as rumored to be flying out of Vandenberg Air Force Base, CA. Now we can add its place of birth to the list, Air Force Plant 42, Palmdale, CA. (Author's collection)

On 5 December 2011, US military sources confirmed that the remains of an RQ-170 had been captured by Iranian forces. Media reports indicated that various US officials declined to confirm whether or not the drone in the video released by Iranian state television was authentic. In this image, Iranian Revolutionary Guards commander Major General Hossein Salami stands next to what Iran presented as an RQ-170 Sentinel drone at Tehran's Islamic Revolution and Holy Defence museum. (ATTA KENARE/AFP via Getty Images)


اسرائیل باید از صحنه روزگار محو شود
Israel must be wiped out of the scene
آمریکا هیچ
Wrong

A model of the RQ-170 Sentinel, captured by Iran in December near the border with Afghanistan, is displayed in front of the Azadi (freedom) tower, as a boy holds a poster showing supreme leader Ayatollah Ali Khamenei, at a rally marking the 33rd anniversary of the Islamic Revolution that toppled the country's pro-Western monarchy and brought Islamic clerics to power, Tehran, Iran. (Vahid Salemi/AP/Shutterstock)

X-55A-ACCA

2009

PROGRAM: X-55A

Name: ACCA (Advanced Composite Cargo Aircraft)

Mission: X-Plane technology demonstrator

Length: 55ft (16.8m)

Wing Span: 68ft 10in (20.98m)

Height: 23ft 9in (7.24m)

Max T.O. Weight: 20,768lb (9,420kg)

First Flight: 9 June 2009

Last Flight: 10 October 2010

Crew: 2

Number Built: 1

Power Plant: 2 x Pratt & Whitney Canada PW306B

Design Speed: Mach 0.61 (466mph; 750km/h)

Service Ceiling: 35,000ft (11,000m)

Combat Radius: N/A

Weapons Load: N/A

The Lockheed Martin X-55 Advanced Composite Cargo Aircraft (ACCA) was an experimental transport aircraft built to demonstrate new cargo aircraft capabilities using advanced composite material. A project of the USAF Air Force Research Laboratory, this aircraft was built by Lockheed Martin at the Skunk Works facility in Palmdale.

The X-55 was based on the existing Fairchild Dornier 328JET airliner. The fuselage was replaced aft of the entrance door with a new, wider fuselage that allowed the loading of cargo through a rear ramp. The new fuselage section was constructed as a single large component, including the vertical stabilizer. First flown in 2009, it was estimated that the X-55 was built for half the cost of a conventional design for a similar aircraft.

In the mid-1990s, the Air Force Research Laboratory (AFRL) acknowledged that even though there was tremendous potential for the incorporation of advanced composites to reduce aircraft structural weights compared to conventional metal structures, the industry was hesitant to implement them in new aircraft.

As a result of this hesitation, AFRL launched the Composites Affordability Initiative to address the perceived risks and barriers. Government labs including NASA worked collaboratively with industry to develop advanced materials and manufacturing technologies. This ten-year AFRL-led research and development effort ultimately led to the ACCA experiment.

The ACCA was conceived by AFRL as a fast track, low-cost development effort. The ACCA was designed in five months, then built and flown 20 months after the go-ahead. Interestingly, the ACCA started out as a Dornier 328 regional airliner whose fuselage and vertical tail were removed and replaced with a new all-composite design structure specifically tailored for the air mobility mission.

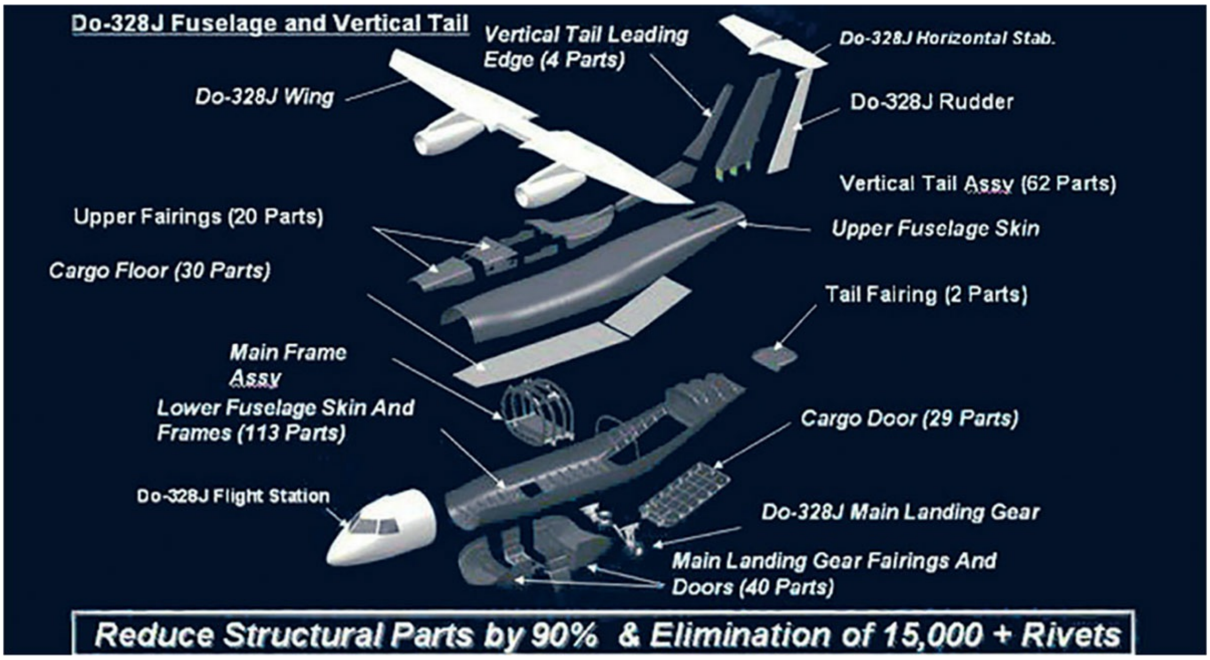
AFRL had just $50 million set aside for this advanced composite manufacturing program and many in industry felt that it would be impossible to develop a composite cargo aircraft for that amount. The team at Skunk Works decided it was possible but only if it used an existing aircraft to cut costs.

In the spirit of exploration and in an effort to demonstrate and test the technologies while keeping costs down and on schedule, the small team modified the high-wing Dornier jet, mating its existing engines, wing, landing gear and avionics systems to the new composite structure.

The program demonstrated the feasibility of designing and manufacturing large, bonded unitized structures featuring low-temperature, out-of-autoclave curing. The fuselage was constructed in two large half-sections (upper–lower) featuring sandwich construction with MTM-45 skins and Nomex core, bonded together with adhesive and ply overlays along the longitudinal seam rather than with the numerous frames, stiffeners and metal fasteners used commonly in traditional aircraft. The vertical tail was designed using tailored stiffness technology. These were joined with the existing Dornier 328J cockpit, wing, engines and horizontal tail.

Compared to the original metallic components, the composite structure used approximately 300 structural parts versus 3,000 metallic parts and approximately 4,000 mechanical fasteners compared to 40,000. The ACCA design was representative of a military transport type aircraft able to carry standard military cargo pallets, passengers or small vehicles.

It was the first of several steps intended to advance the readiness of multiple technologies needed for the next generation of theater airlift aircraft. The ACCA demonstrated how future aircraft designs and manufacturing processes can be tailored through the use of advanced composites and new structural concepts to significantly shorten design spans, reduce aircraft size and structural weight, accelerate manufacturing processes, reduce tooling costs and reduce assembly labor. Initial estimates suggest that development costs could be reduced by 25 percent or more over today's processes plus additional operating cost savings from less weight resulting in lower fuel burn.


Do-328J Fuselage and Vertical Tail
Vertical Tail Leading Edge (4 Parts)
Do-328J Horizontal Stab.
Do-328J Wing
Do-328J Rudder
Vertical Tail Assy (62 Parts)
Upper Fairings (20 Parts)
Upper Fuselage Skin
Cargo Floor (30 Parts)
Tail Fairing (2 Parts)
Main Frame Assy
Lower Fuselage Skin And Frames (113 Parts)
Cargo Door (29 Parts)
Do-328J Flight Station
Do-328J Main Landing Gear
Main Landing Gear Fairings And Doors (40 Parts)
Reduce Structural Parts by 90% & Elimination of 15,000 + Rivets

An illustrated layout of the major components used during the modification and reassembly of the X-55A. (Lockheed Martin)

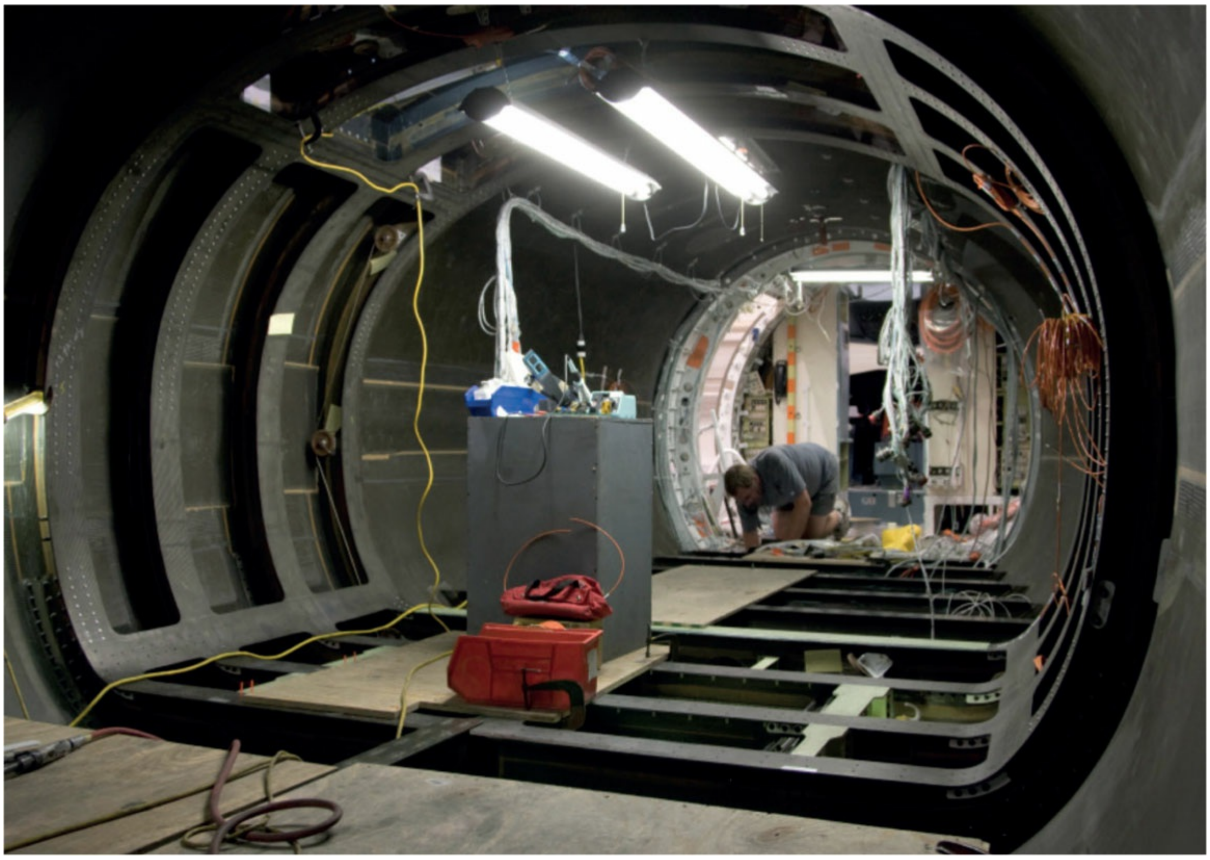
The X-55A-ACCA is shown on its maiden flight on 9 June 2009 as it takes off from the Palmdale Regional Airport, also known as Air Force Plant 42. (Lockheed Martin)

Bottom view of the X-55A-ACCA as passes over the Palmdale Regional Airport runway threshold on its first flight. (Lockheed Martin)

The X-55A-ACCA was conceived by the Air Force Research Laboratory (AFRL) and was designed in five months, then built and flown 20 months after the go-ahead.

(Lockheed Martin)

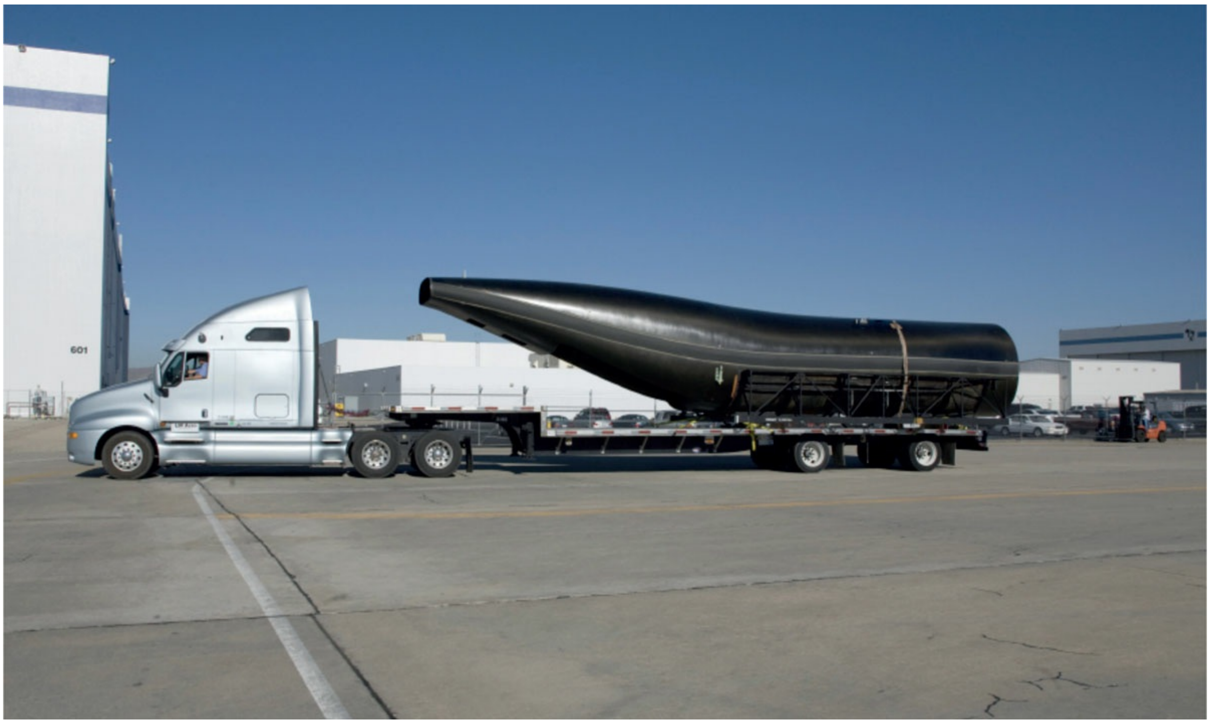
Compared to the original metallic components, the structure used approximately 300 structural parts versus 3,000 metallic parts and approximately 4,000 mechanical fasteners compared to 40,000. (Lockheed Martin)



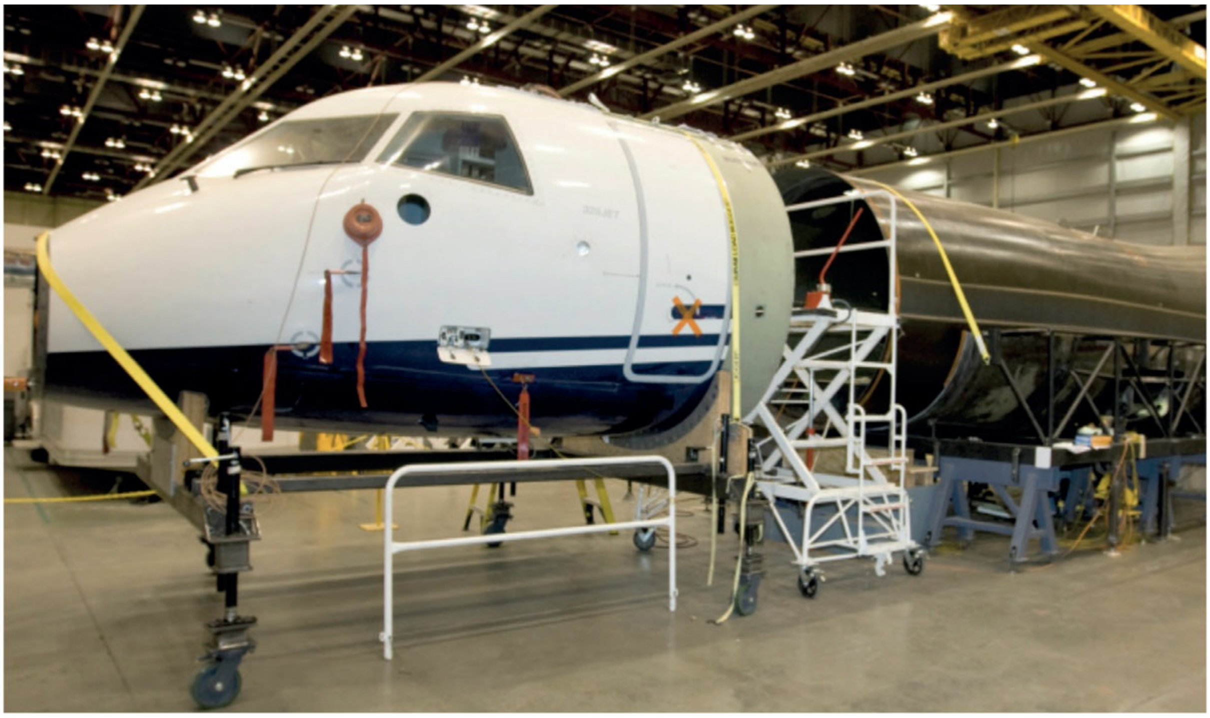
An inside view of the interior of the X-55A during the construction and bonding of the composite parts and assemblies. (Lockheed Martin)

CARBON COMET
001

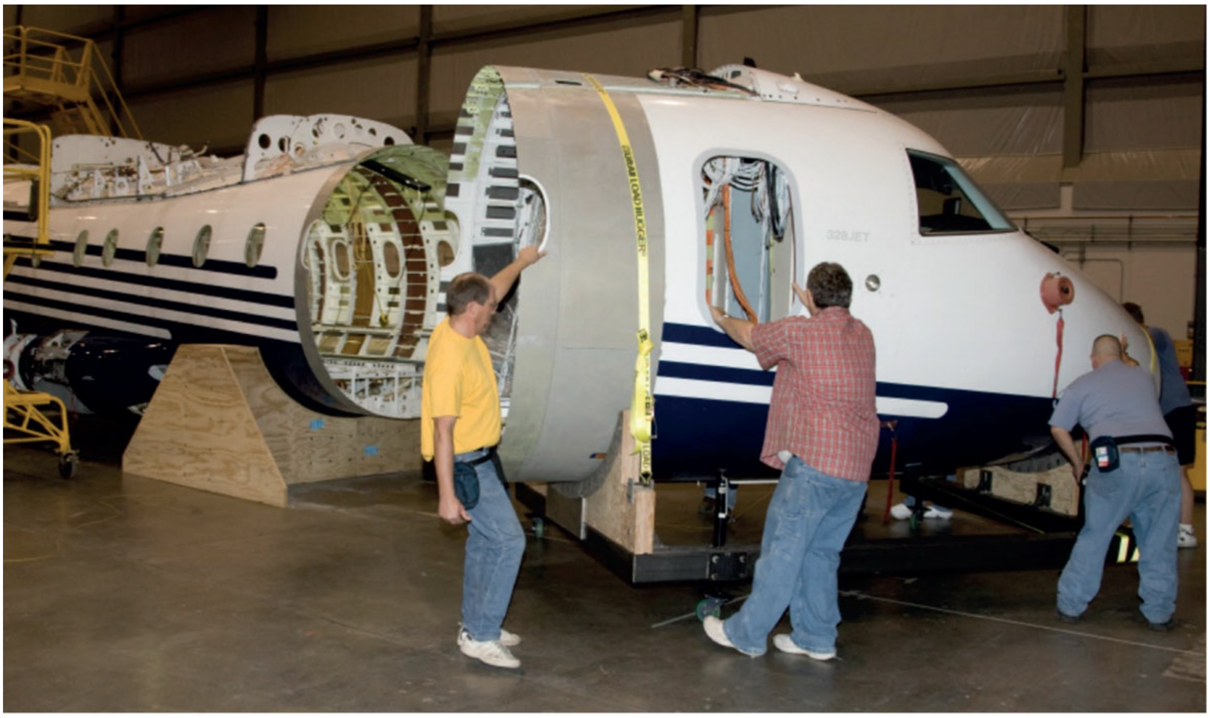
The X-55A program demonstrated the feasibility of designing and manufacturing large, bonded unitized structures. The fuselage was constructed in two large half-sections featuring sandwich construction. (Lockheed Martin)



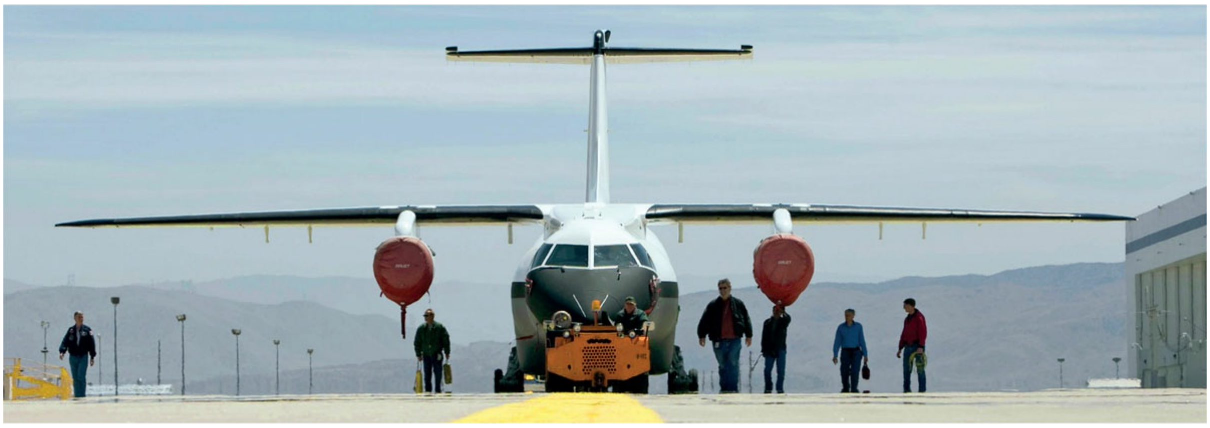
The finished and bonded two-part fuselage is moved to the reassembly area at the Lockheed Martin Skunk Works at Air Force Plant 42, Palmdale. (Lockheed Martin)



Lockheed Martin technicians prepare the complete cockpit of the Dornier 328JET donor aircraft to the partially completed composite fuselage. (Lockheed Martin)



A team of production technicians moves the just detached cockpit of the Dornier 328JET donor aircraft to an area of the hangar as it awaits its reattachment to the new composite fuselage. (Lockheed Martin)



The completed X-55A-ACCA is towed to the engine runup area of the Skunk Works prior to its very first flight on 9 June 2009. (Lockheed Martin)

N807LM
ACCA

The X-55A-ACCA as it lifts off the Palmdale runway for the first time. (Lockheed Martin)

N807LM
ACCA

The X-55A-ACCA test bird now calls Blackbird Airpark in Palmdale its permanent home. The museum is open Friday – Sunday and is subject to volunteer availability and weather. Admission is free. (Lockheed Martin)

HTV-2

2010

PROGRAM: HTV-2

Name: Hypersonic Technology Vehicle 2

Mission: Technology demonstrator

Length: N/A

Wing Span: N/A

Height: N/A

Max T.O. Weight: N/A

First Flight: 22 April 2010

Last Flight: 11 August 2011

Crew: Unmanned

Number Built: 2

Power Plant: Minotaur IV Lite

Design Speed: Mach 17.53 (13,000mph; 21,000km/h)

Service Ceiling: Suborbital

Combat Radius: Global

Weapons Load: N/A

DARPA's Falcon Hypersonic Technology Vehicle 2 (HTV-2) program was a multi-year research and development effort to increase the technical knowledge base and advance critical technologies to make long-duration hypersonic flight a reality. Data from the program informed policy, acquisition and operations decisions for future Department of Defense (DoD) Conventional Prompt Global Strike programs. Hypersonic data was collected through extensive modeling and simulation, wind-tunnel testing and two experimental flight-tests. The ultimate goal was a capability that could reach anywhere in the world in less than an hour.

Falcon HTV-2 was an unmanned, rocket-launched, maneuverable aircraft that glided through the Earth's atmosphere at incredibly fast speeds – Mach 20 (approximately 13,000mph). At HTV-2 speeds, flight time between New York City and Los Angeles would be less than 12 minutes. The HTV-2 vehicle was a "data truck" with numerous sensors that collected data in an uncertain operating envelope.

In 2020, the mastery of three key technical challenges stands between the DoD and long-duration hypersonic flight: aerodynamics, aero-thermal effects, and critical guidance, navigation and control.

HTV-2 flew its maiden flight on 22 April 2010, collecting nine minutes of unique flight data, including 139 seconds of Mach 12 to Mach 17 aerodynamic data.

Flight one achieved many "firsts":

- It deployed the largest number of sea, land, air and space data collection assets in support of a hypersonic flight-test.
- It maintained Global Positioning System (GPS) signals while traveling 3.6mps.
- It validated two-way communication with the vehicle.
- It verified effective use of the Reaction Control System (RCS).

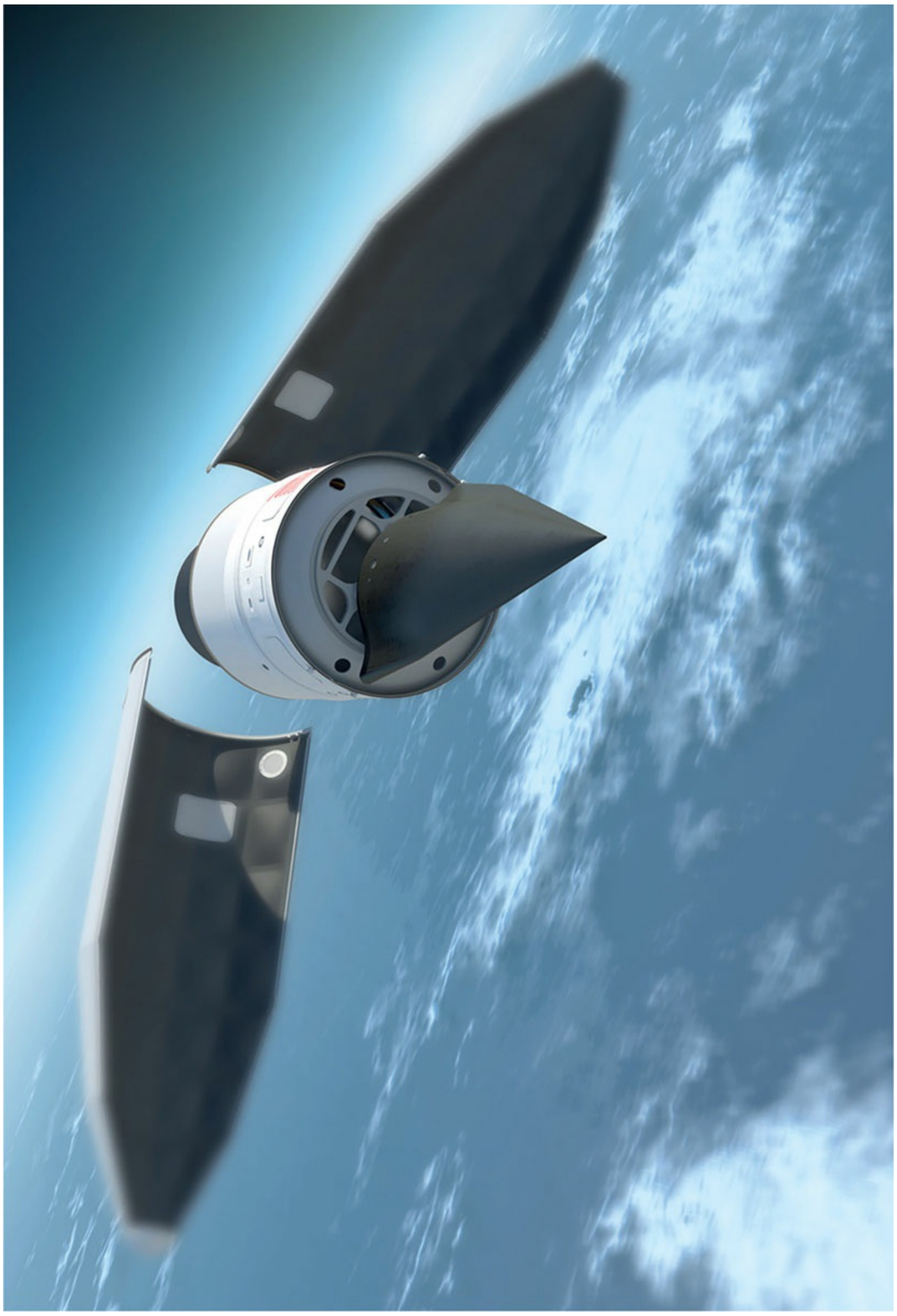
The second and final planned flight-test was scheduled for August 2011. First flight lessons learned, high-speed wind tunnel testing and computer simulations were used to improve aerodynamic models and to optimize the vehicle design and trajectory for flight two.

The second test flight began with launch at 7.45am Pacific Time. The Minotaur IV vehicle successfully inserted the aircraft into the desired trajectory. Separation of the vehicle was confirmed by rocket camera and the aircraft transitioned to Mach 20 aerodynamic flight. This transition represented a critical knowledge and control point in maneuvering atmospheric hypersonic flight. According to DARPA:

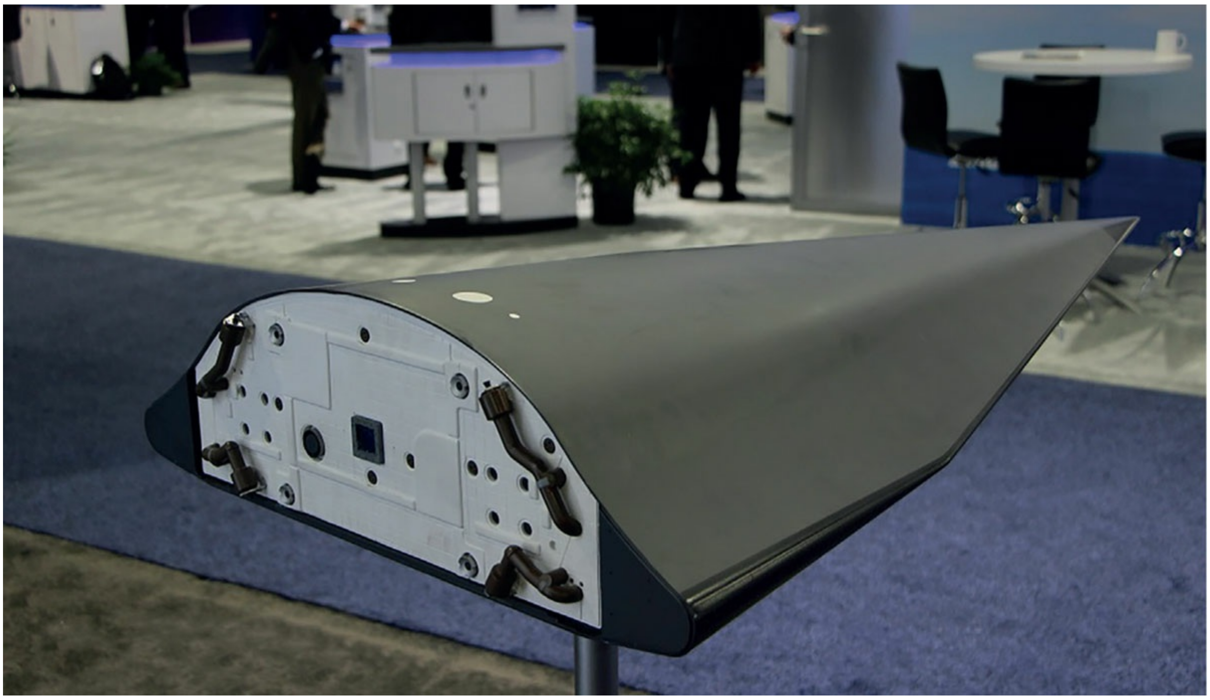
> … a gradual wearing away of the vehicle's skin as it reached stress tolerance limits was expected, however, larger than anticipated portions of the vehicle's skin peeled from the aero structure. During the flight-test, which lasted nine minutes, the HTV-2 was actually flying in a controlled manner for three minutes.
>
> The data was collected before an anomaly caused loss of signal. Initial indications are that the aircraft impacted the Pacific Ocean along the planned flight path.
>
> Here's what we know, we know how to boost the aircraft to near space. We know how to insert the aircraft into atmospheric hypersonic flight. We do not yet know how to achieve the desired control during the aerodynamic phase of flight. It's vexing; I'm confident there is a solution. We have to find it.

"Prior to its first test flight, the technical team completed the most sophisticated simulations and extensive wind tunnel tests possible. But these ground tests had not yielded the necessary knowledge. Filling the gaps in the understanding of hypersonic flight in this demanding regime requires that we be willing to fly," said DARPA Director Regina Dugan. "In the April 2010 test, we obtained four times the amount of data previously available at these speeds."

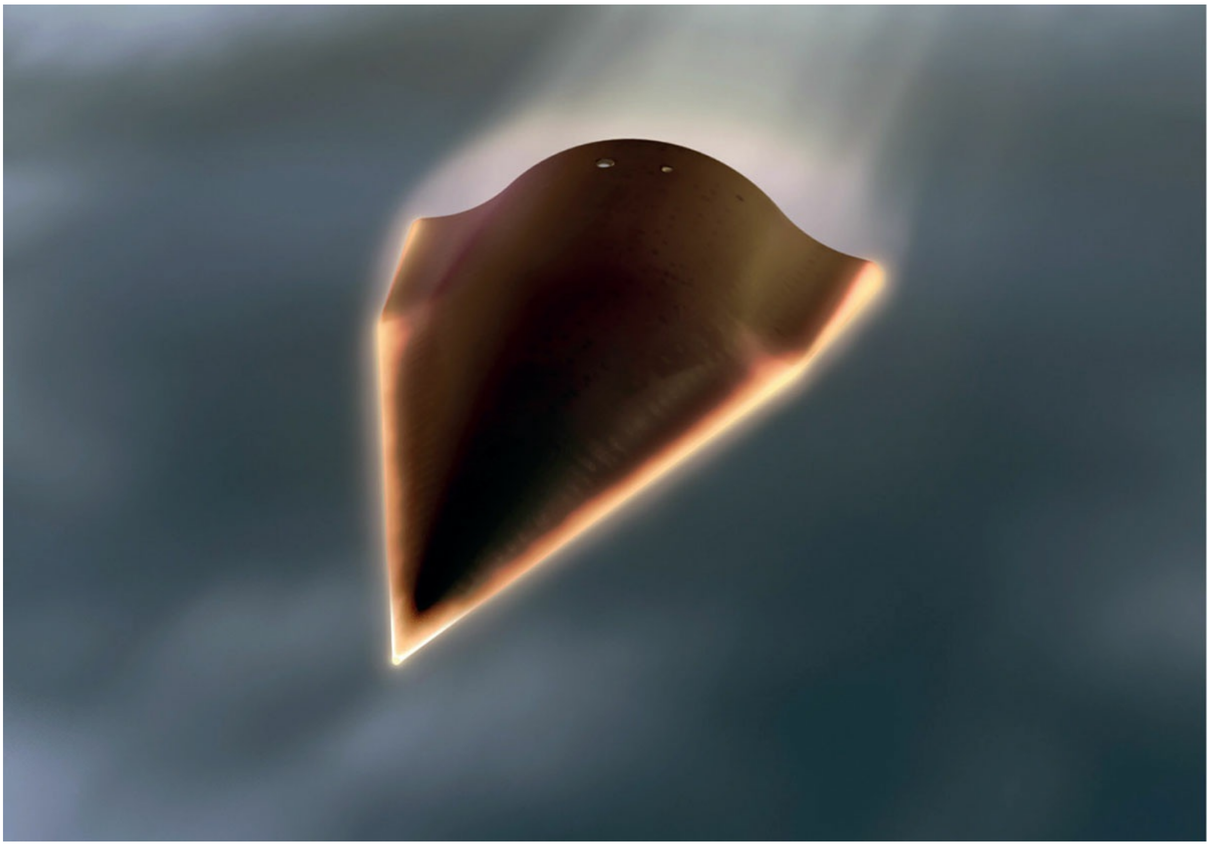
The assembled independent Engineering Review Board reviewed and analyzed the data collected. This data formed policy, acquisition and operational decisions for future Conventional Prompt Global Strike programs – the goal of which, ultimately, is to have the capability to reach anywhere in the world in less than one hour.



An artist's rendering of the DARPA/Lockheed Martin HTV-2 shroud separating from the Minotaur IV Lite Launch vehicle. (DARPA)



A mockup of the HTV-2 at an Air Force association gathering. (Lockheed Martin)

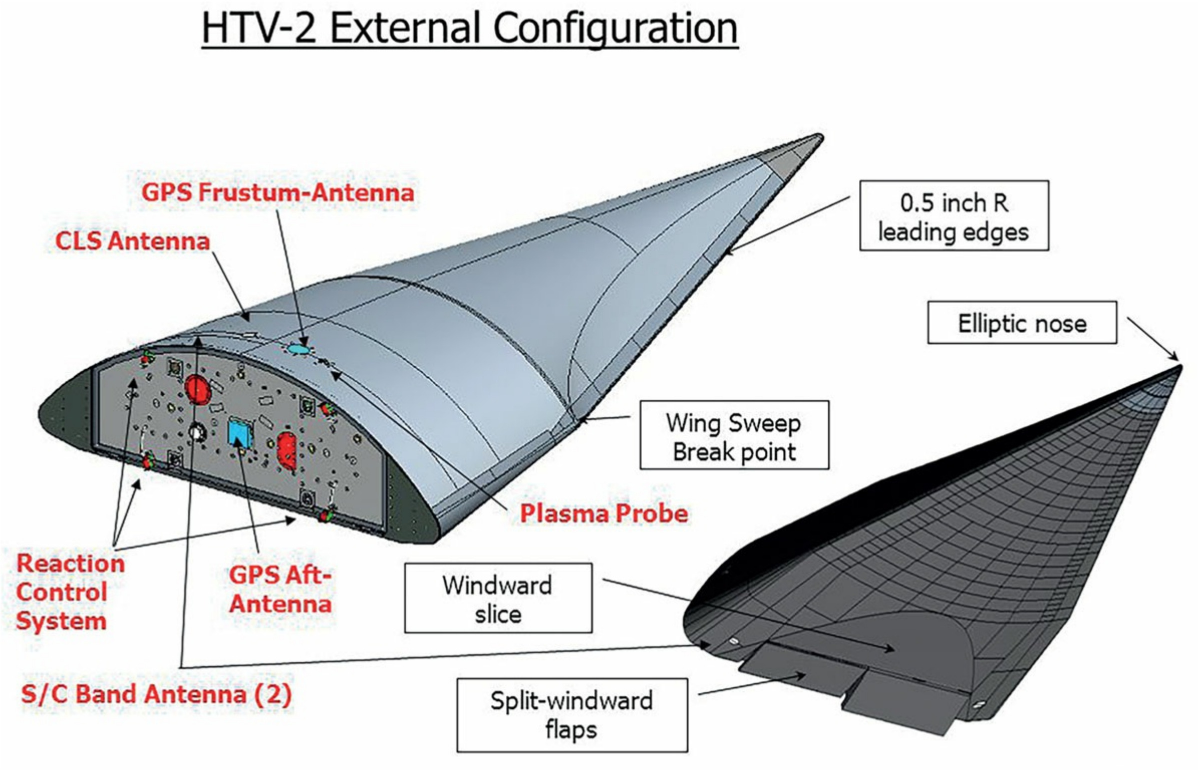


An artist's rendering of the HTV-2 entering the upper atmosphere during its Mach 17 second flight. (DARPA)

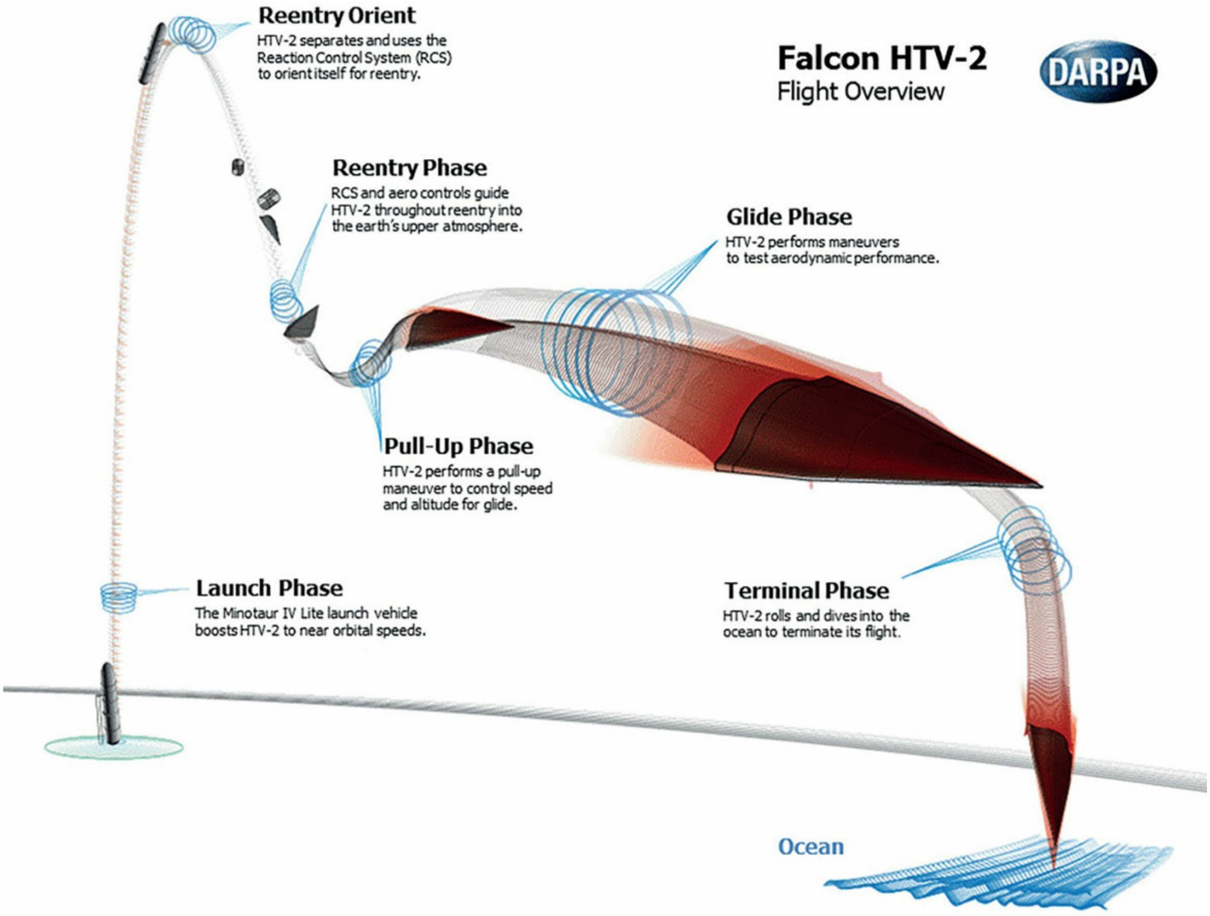
An evolution drawing showing the stages from concept to wind tunnel model to final design. (DARPA)

FALCON
Orbital
DARPA
TASC
USAF

The HTV-2 sits atop an Orbital Science Minotaur IV Lite rocket at SLC-8, Vandenburg AFB, CA, prior to launch on 11 August 2011. (DARPA)


HTV-2 External Configuration
GPS Frustum-Antenna
CLS Antenna
0.5 inch R leading edges
Elliptic nose
Wing Sweep Break point
Plasma Probe
Reaction Control System
GPS Aft-Antenna
Windward slice
S/C Band Antenna (2)
Split-windward flaps

Drawing of the HTV-2's external configuration. (DARPA)


Reentry Orient
HTV-2 separates and uses the Reaction Control System (RCS) to orient itself for reentry.
Falcon HTV-2
Flight Overview
DARPA
Reentry Phase
RCS and aero controls guide HTV-2 throughout reentry into the earth's upper atmosphere.
Glide Phase
HTV-2 performs maneuvers to test aerodynamic performance.
Pull-Up Phase
HTV-2 performs a pull-up maneuver to control speed and altitude for glide.
Launch Phase
The Minotaur IV Lite launch vehicle boosts HTV-2 to near orbital speeds.
Terminal Phase
HTV-2 rolls and dives into the ocean to terminate its flight.
Ocean

The Falcon HTV-2 flight overview. (DARPA)

RATTLRS

2010

PROGRAM: BGM-178

Name: RATTLRS (Revolutionary Approach To Time-critical Long Range Strike)

Mission: Long range strike

Length: 21ft (6.4m)

Wing Span: Diameter 1ft 8in (520mm)

Height: N/A

Max T.O. Weight: 2,000lb (907kg)

First Flight: N/A

Last Flight: N/A

Crew: Unmanned

Number Built: Components and power plant

Power Plant: 1 x Rolls Royce YJ102R turbojet

Design Speed: Mach 3+ (2,150mph; 3,460km/h)

Service Ceiling: >90,000ft (>27,500m)

Combat Radius: 500 miles (434nm; 805km)

Weapons Load: 500lb (226.8kg) penetrating high-explosive or submunitions-

dispensing warhead

The state-of-the-art technologies within the Revolutionary Approach To Time-critical Long Range Strike (RATTLRS) vehicle were designed to give tomorrow's warfighters a leap ahead in capability combined with greater flexibility, without increased logistical burden. Sponsored by the Office of Naval Research (ONR), supported by the Air Force, NASA and DARPA, RATTLRS was a supersonic, science and technology missile flight demonstrator. The end result was intended to be a high-supersonic cruise missile capable of speeds greater than Mach 3 that could be launched from Navy and Air Force platforms including surface ships, submarines and aircraft.

Lockheed Martin teamed with Allison Advanced Development Company (AADC) in the RATTLRS project to develop technologies to provide an advanced Mach 4+ integrated propulsion system in an operationally traceable airframe. The AADC YJ102R engine provided the supersonic cruise capability of the legendary SR-71 spy plane in a simple and inexpensive engine suitable for an expendable missile. Advances in turbine cooling technology in the almost 60 years since the Blackbirds first flew allowed the YJ102R to provide more than six times the specific thrust of the SR-71 engines, allowing the RATTLRS vehicle to cruise at similar Mach numbers without the high fuel consumption of afterburning engines.

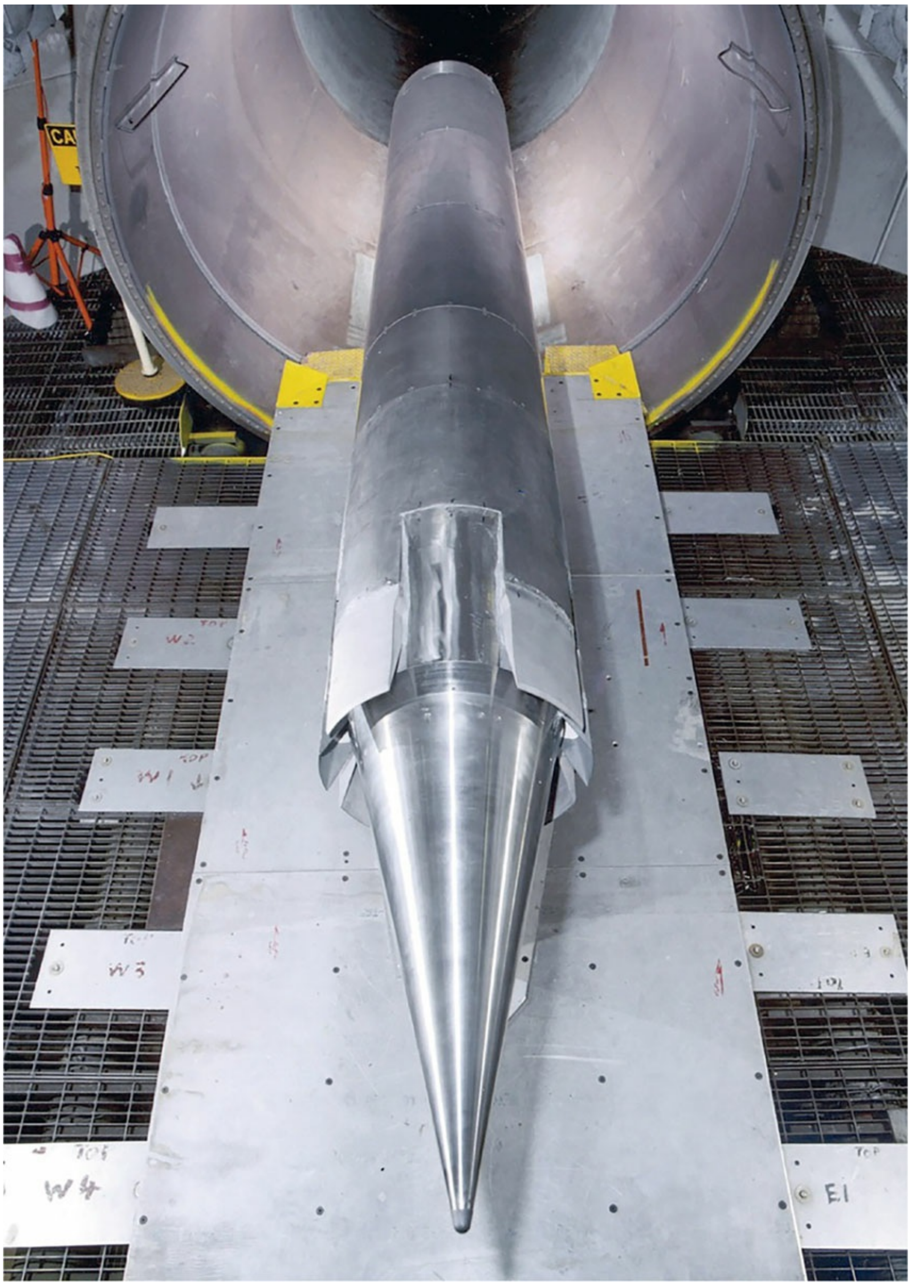
Lockheed Martin completed proof pressure testing of the RATTLRS at the high-speed wind tunnel complex at Arnold AFB complex near Tullahoma, TN. This testing validated the vehicle's structural integrity and was a crucial step in the development of the flight demonstration vehicle. The testing was a significant milestone as the RATTLRS entered into final integration and system checkouts prior to flight demonstrations planned for early 2008 that never took place. The RATTLRS vehicle was to flight-demonstrate an integrated turbine engine and airframe propulsion system capable of flight at speeds above Mach 3+ (more than 2,000mph).

Before cancelation due to cost over runs and technical issues, RATTLRS was in development and demonstration phase with its first flight-test scheduled for late 2007 or early 2008. Lockheed Martin was the prime weapon system integrator and Rolls Royce-Liberty Works was the engine developer.

Lockheed Martin Missile and Fire Control was cooperating in the RATTLRS weapon system development and in 2005, Lockheed Martin was studying the chance of a boosted penetrator to arm the RATTLRS, which would be far more effective against hardened and buried targets. The program was expected to experience further development during 2006.

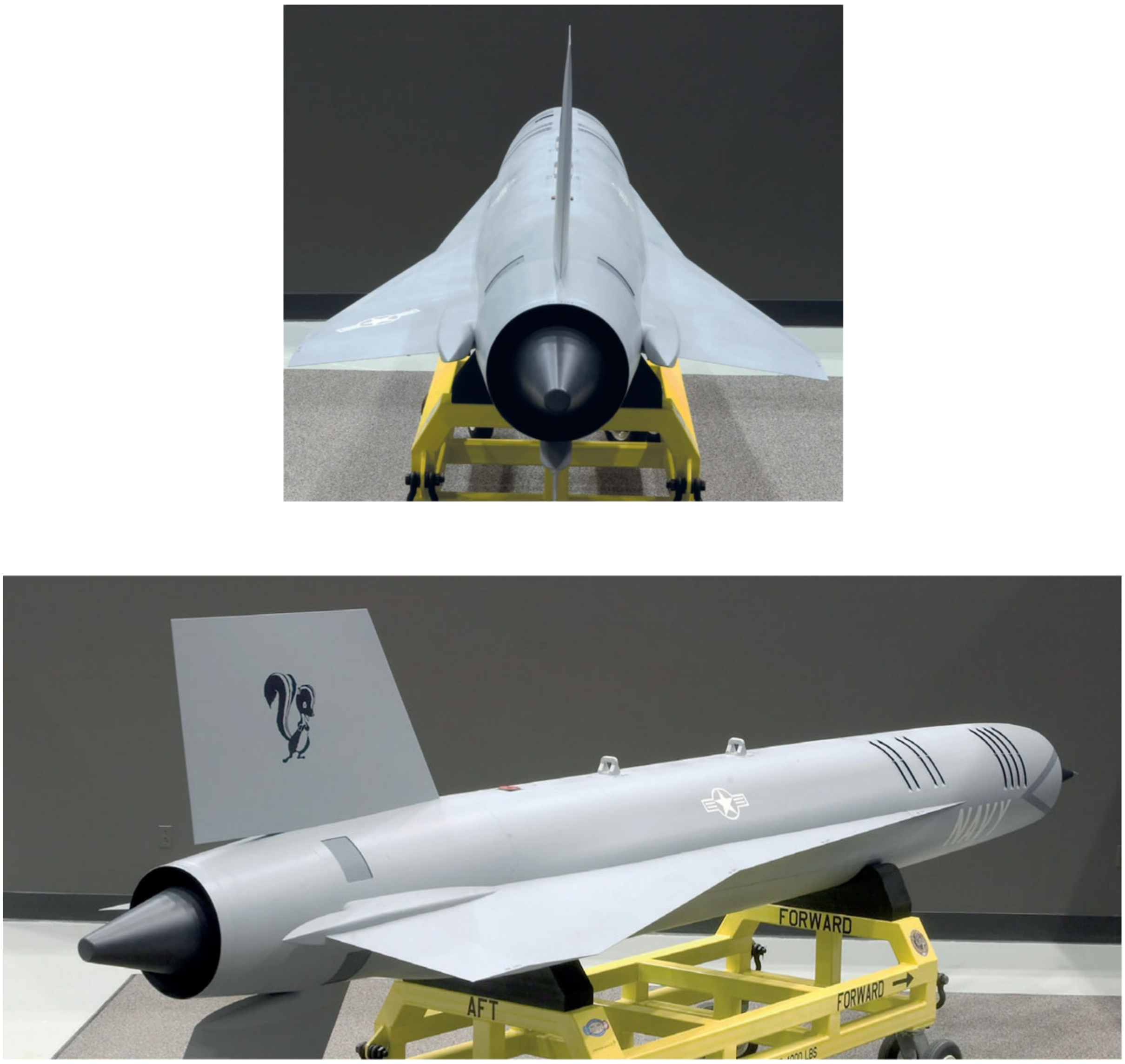
On 18 October 2006, Lockheed Martin completed penetrator warhead sled tests to successfully conclude the high-speed payload employment-testing component of its RATTLRS effort. A simulated nose and inlet structure of an air-breathing cruise missile demonstrated warhead penetration performance and survivability against hardened bunkers. During the tests, the RATTLRS airframe was accelerated to supersonic speeds of greater than Mach 2. The warhead penetrated cleanly and completely through the concrete barriers. Recovered hardware showed that the warhead remained structurally intact.

During the late 2000s, the prototype RATTLRS air vehicles were to undergo flight-test evaluations. The Lockheed Martin RATTLRS (BGM-178) had been designed and slated to replace the Raytheon BGM-109 Tomahawk cruise missile, but it never came to be. There is no new information on the RATTLRS program released by either Lockheed Martin or the ONR, and as of this writing the program was terminated.



The early inlet design for the BGM-178 being tested at the Arnold Air Force Base, Tullahoma, TN, complex of high-speed wind tunnels. (AEDC photo)

NAVY
FORWARD
AFT
← FORWARD
MAX LOAD 4000 LBS
MAX LOAD 4000 LBS


NAVY
FORWARD
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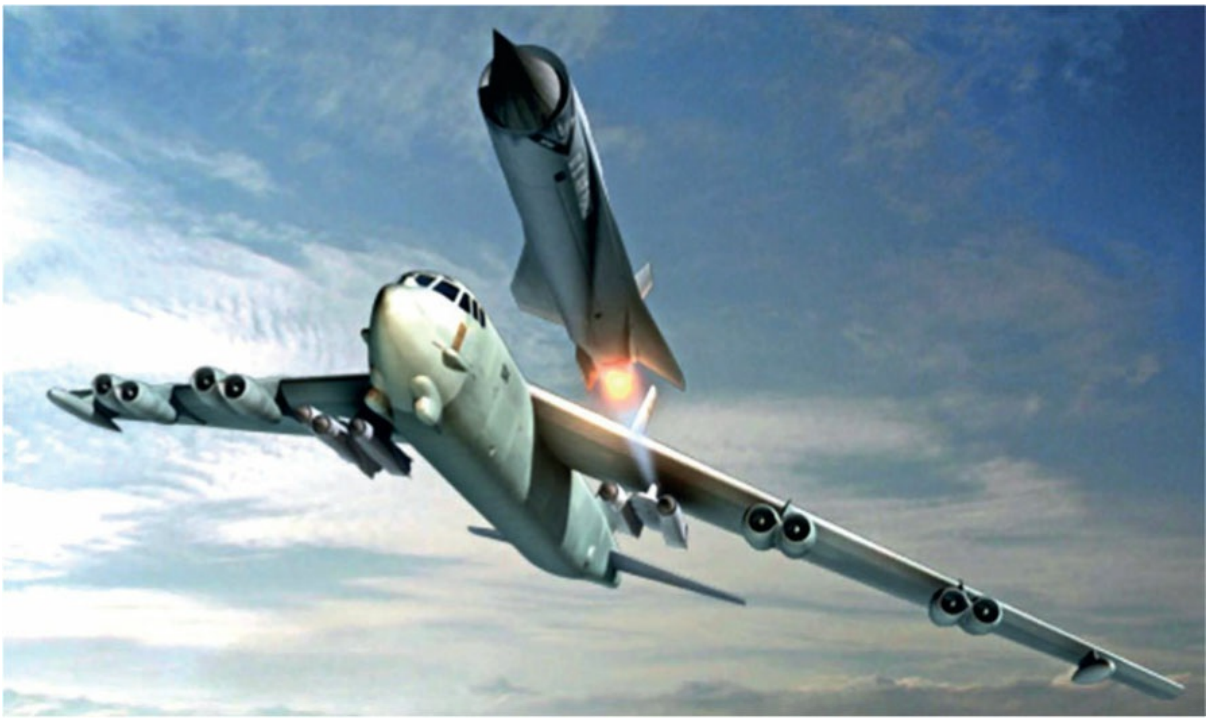
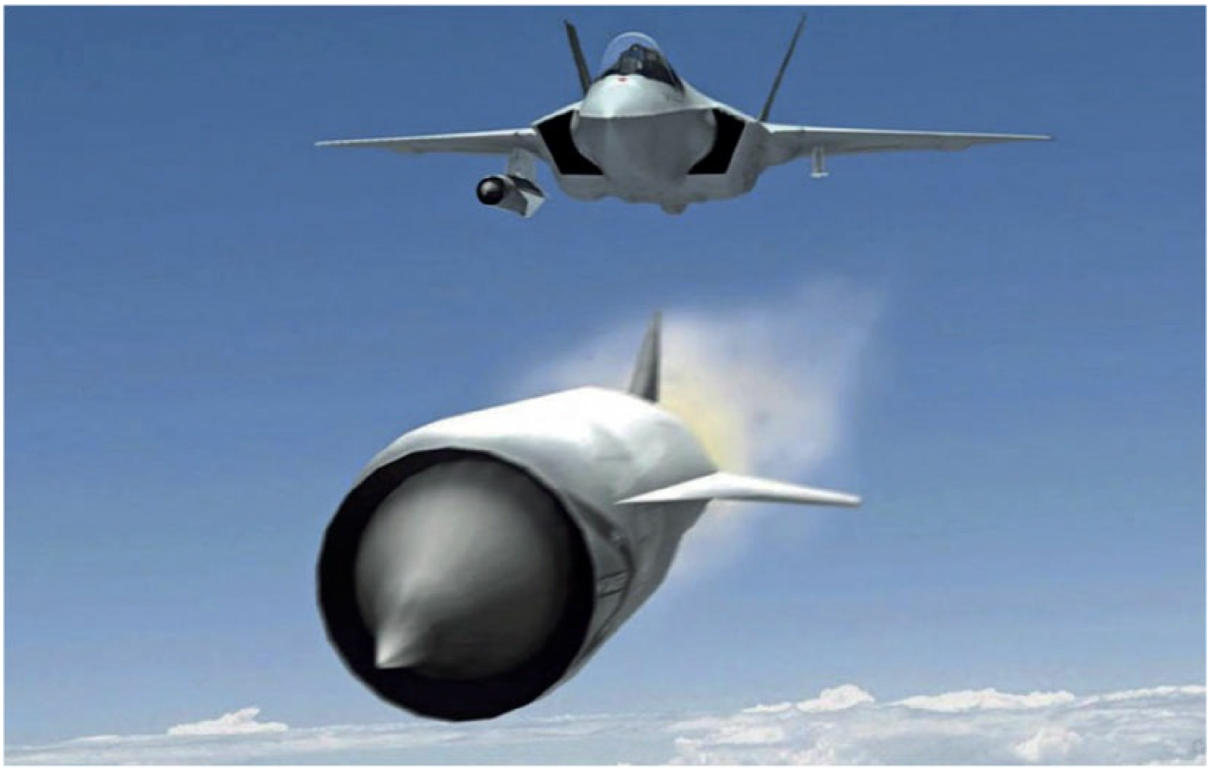
FORWARD

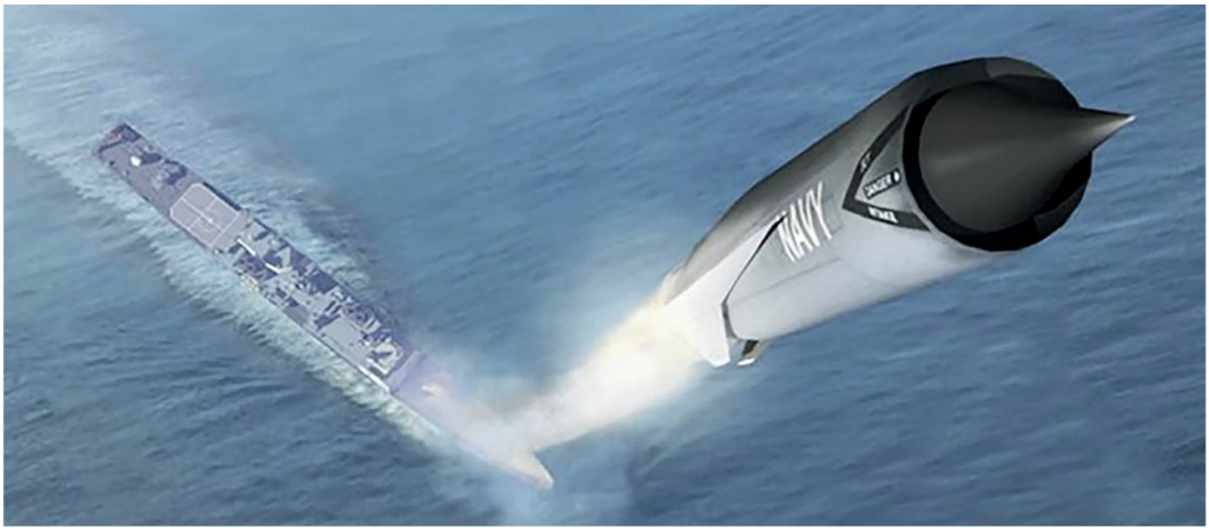
A walk around of the full-size mockup of the BGM-178 that was developed at the Lockheed Martin Skunk Works starting in mid-2000s. (Lockheed Martin)



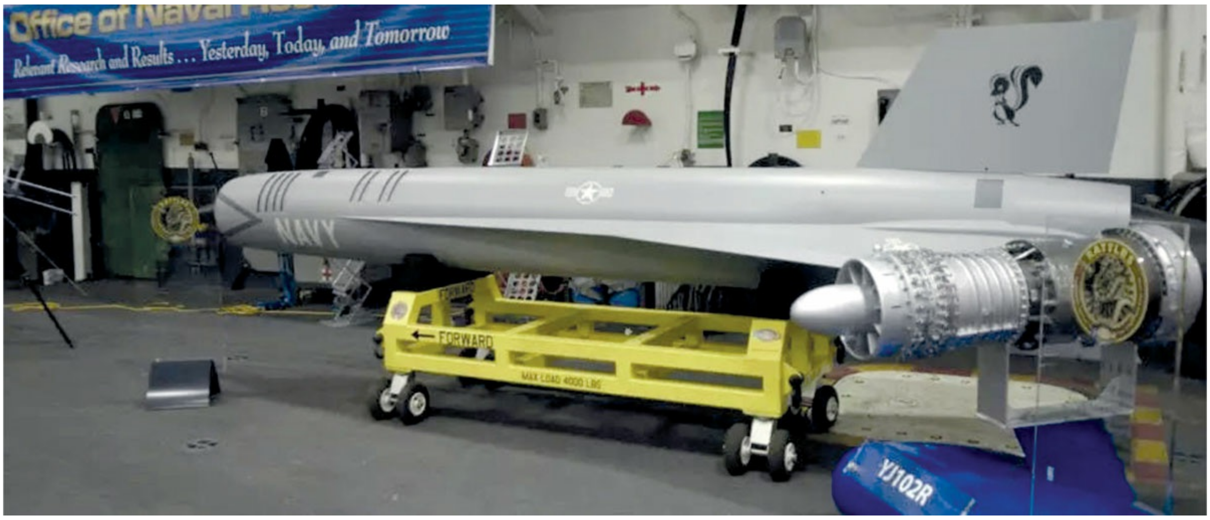
Artist rendering of an Air Force/Boeing B-52H Stratofortress launching the Lockheed Martin BGM-178. (Lockheed Martin)



The BGM-178 is shown being launched from an external pylon from a Lockheed Martin F-35. (Lockheed Martin)



The Lockheed Martin BGM-178 can be launched from the air, from surface ships and from submerged SSN and SSGN class submarines. (Lockheed Martin)


Office of Naval Research
Relevant Research and Results… Yesterday, Today, and Tomorrow
NAVY
FORWARD
MAX LOAD 4000 LBS
YJ102R

An example of the full-sized mockup of the BGM-178 on public display during an Office of Naval Research "Show and Tell" during New York City Fleet Week 2007 on board the USS *Wasp* (LHD 1) at Pier 90, Manhattan, NY. (US Navy)

X-56A

2013

PROGRAM: X-56A

Name: MUTT (Multi-Utility Technology Testbed)

Mission: X-Plane technology demonstrator

Length: 7ft 6 in (2.3m)

Wing Span: 27ft 6in (8.4m)

Height: N/A

Max T.O. Weight: 480lb (218kg)

First Flight: 26 July 2013

Last Flight: Still in flight-test

Crew: 1 – ground based operator

Number Built: 2

Power Plant: 2 x JetCat P400 turbojets

Design Speed: Mach 0.18 (138mph; 222km/h)

Service Ceiling: N/A

Combat Radius: N/A

Weapons Load: N/A

Long, thin, high-aspect-ratio wings are considered crucial to the design of future long-range aircraft, including fuel-efficient airliners and cargo transports. Unlike the short, stiff wings found on most aircraft today, slender, flexible airfoils are susceptible to uncontrollable vibrations, known as flutter, and may be stressed by bending forces from wind gusts and atmospheric turbulence.

In order to improve ride quality, efficiency, safety and the long-term health of flexible aircraft structures, NASA is investigating key technologies for active flutter suppression and gust-load alleviation. Research in these areas is being conducted at NASA's Armstrong Flight Research Center with the X-56A Multi-Utility Technology Testbed, a small, remotely piloted experimental aircraft developed by Lockheed Martin Skunk Works for the Air Force Research Laboratory (AFRL). In addition, NASA Armstrong has conducted follow-on testing with the X-56A to support research on lightweight structures and advanced control technologies for future efficient, environmentally friendly transport aircraft.

The sub-scale aircraft is 7.5ft long, has a 28ft wing span, weighs about 480lb, and is powered by two small 90lb-thrust JetCat P400 turbojet engines. The modular X-56A system includes two center bodies, a set of stiff wings, three sets of flexible wings, a ground control station and a transportation trailer. The X-56A has easily removed wings and is convertible to other wing configurations, such as a joined-wing platform or a wing-tail configuration. The aircraft is equipped with a ballistic parachute recovery system, which is intended to recover the fuselage and the majority of the aircraft systems in the event of an in-flight wing failure.

The initial flight-tests of the X-56A system, performed by Lockheed and AFRL in the latter half of 2013 and extending into early 2014, collected flight data on highly flexible structures and flutter suppression control technology. Initially flown with a conventional stiff wing, the aircraft was subsequently being used to evaluate active flutter suppression with the flexible wings from early 2014. After these flights are completed, the X-56A will be transferred to NASA Dryden to be used for research into lightweight structures and advanced control technologies for future efficient, environmentally friendly transport aircraft.

Under a five-year project supported by the Fixed Wing Project of NASA's Fundamental Aeronautics program, NASA is developing a flexible-wing flight control system and advanced sensors to measure wing shape and detect airflow separation. The project plans to use these to fly the X-56A with a slender, flexible wing with a much higher aspect ratio than currently used on commercial airliners. Research results from the low-speed sub-scale X-56A will benefit future designs for both subsonic and supersonic.

The goal of the X-56A project is to advance aeroservoelastic technology through flight research using a low-cost, modular, remotely piloted aircraft. The aircraft is being tested using flight profiles where flutter occurs in order to demonstrate that onboard instrumentation can not only accurately predict and sense the onset of wing flutter, but also be used by the control system to actively suppress aeroelastic instabilities.

Applied to future designs, such technologies will enable construction of longer, lighter, more flexible wings for a variety of crewed and remotely piloted aircraft. NASA engineers will explore issues related to active flutter suppression by adjusting software programs in the X-56A aircraft's flight control computer. Researchers also expect to learn how to better ease gust loads, which will make flexible airplanes safer during encounters with in-flight turbulence. Several key goals include:

- Maturation of flutter-suppression technologies.
- Reduction of structural weight to improve fuel efficiency and range.
- Increasing aspect ratio by 30 to 40 percent to reduce aerodynamic drag.
- Promoting improved long-term structural integrity by reducing gust loads.

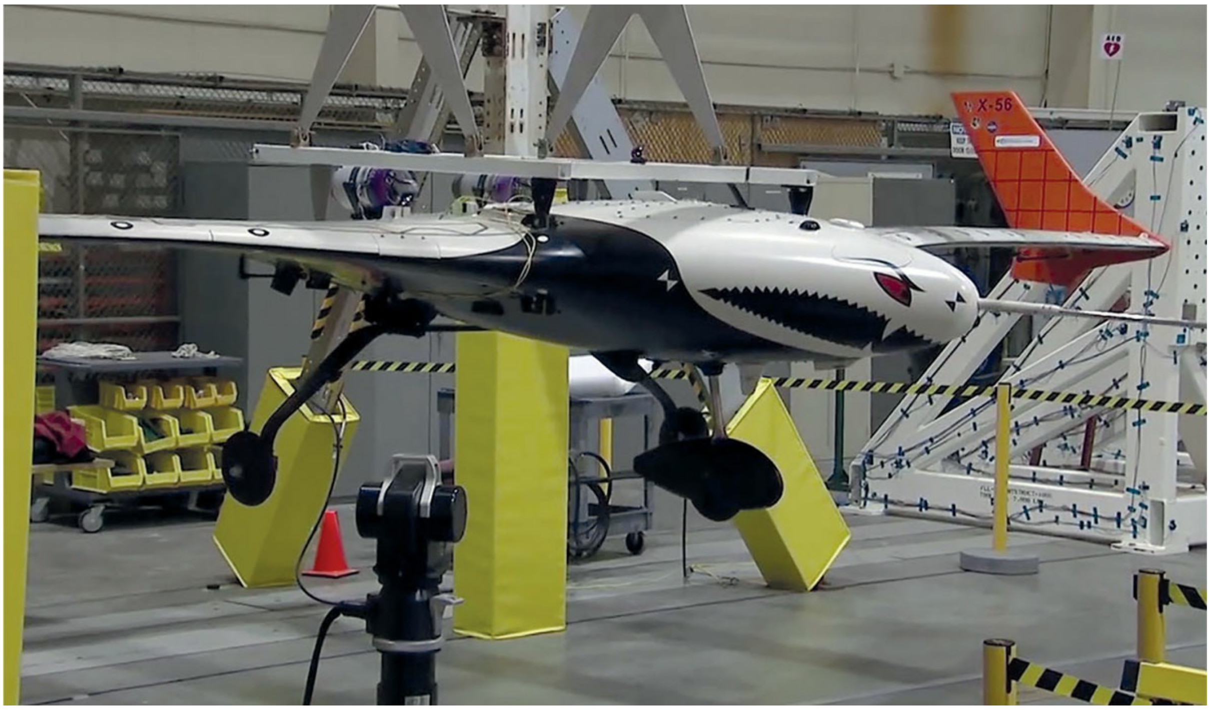
Designing the next generation of aerospace vehicles will pose serious challenges in modeling, predicting and controlling potentially destructive aeroservoelastic. The X-56A was designed and built to test to the edge of the flight envelope in an effort to mature technologies that will lead to more slender, lightweight, high-aspect-ratio wings, resulting in better aircraft performance.

The X-56A is designed as a "flying wing" blended-body air vehicle with vertical surfaces added at the wing tips. The fuselage houses the twin-engine arrangement, avionics and fuel stores while the undercarriage is of a wheeled tricycle arrangement. (NASA)

The first of two X-56As is trailered and ready to be taken out to Rogers Dry Lake for a test flight. (NASA)

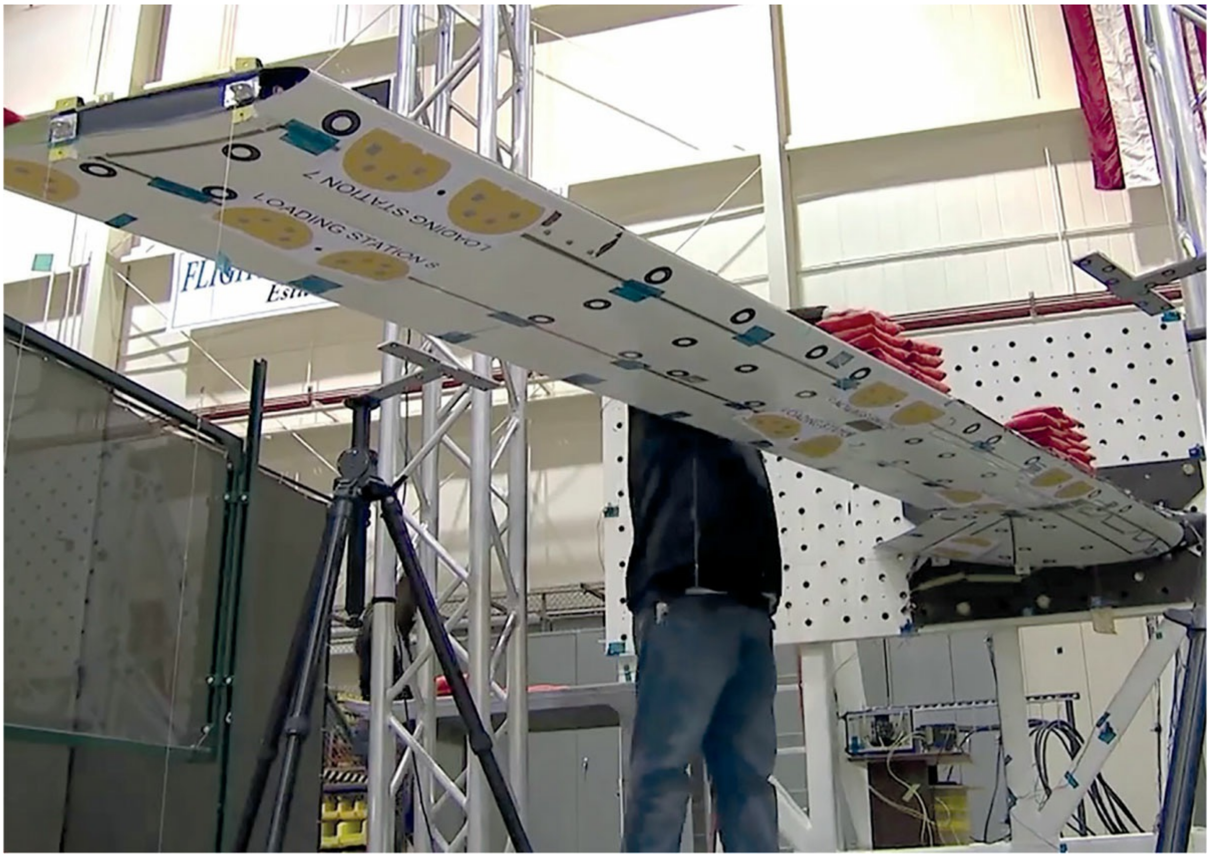
The X-56A Multi-Utility Technology Testbed climbs after liftoff from the bed of Rogers Dry Lake at Edwards AFB during its second test flight. (Lockheed Martin)

GHT LOADS LA ORY
Established 196



The X-56A undergoes loads testing to determine the maximum amount of structural flex to expect during the most extreme maneuvers the X-56A would experience. (NASA)

The sub-scale X-56A Multi-Utility Technology Testbed is controlled by two pilots in a ground control station designed specifically for this flight-test program. (Lockheed Martin)



The long, thin, high-aspect-ratio wings are considered crucial to the design of future long-range aircraft, including fuel-efficient airliners and cargo transports. (NASA)

The second X-56A unmanned aircraft flew for the first time on 9 April 2015 while under operation by NASA. The aircraft flew eight flights with the stiff wings to clear its operating envelope. The vehicle then completed its first flight with the highly flexible wings on 31 August 2017. (NASA)

90
135
LOCKHEED MARTIN
X-56

The X-56A flies over the Edwards AFB iconic compass on Rogers Dry Lake. (NASA)

A NASA launch team prepares the X-56A for flight. Researchers are using the aircraft to investigate if highly flexible, lightweight wings can be controlled. (NASA)

An Air Force ground launch crewman readies the X-56A for a test flight. (Lockheed Martin)

The X-56A on final approach to land on Rogers Dry Lake. (NASA)

SEA GHOST

2013

PROGRAM: UCLASS

Name: Sea Ghost

Mission: Aerial tanker

Length: 14ft 9in (4.5m)

Wing span: 90ft (27.43m)

Height: 6ft (1.8m) estimated

Max T.O. Weight: Unknown

Ferry Range: Classified

First Flight: Mockup only

Last Flight: N/A

Crew: Unmanned

Number Built: N/A

Power Plant: 1 x Garrett TFE731

Design Speed: Subsonic

Service Ceiling: 35,000ft (10,670m)

Combat Radius: Classified

Weapons Load: Air-to-air refueler

Lockheed Martin's Skunk Works unveiled its Unmanned Carrier-Launched Airborne Surveillance and Strike (UCLASS) contender in 2013. The tailless, flying-wing design concept bears more than a passing resemblance to the company's successful, if somewhat hush-hush RQ-170 Sentinel UAV, and shares a number of its technical features.

Designed from the outset for stealth, with advanced signature control, communications and bandwidth management, the Sea Ghost incorporates proven technologies from both the Sentinel and the F-35, and is intended to support persistent carrier-based intelligence, surveillance and reconnaissance (ISR), and light strike missions. In service, it will carry electro-optical sensors, supported by open architecture avionics which will simplify the addition of new sensors and systems to accommodate future developments in technology and mission demands, and be able to house two 1,000lb munitions internally.

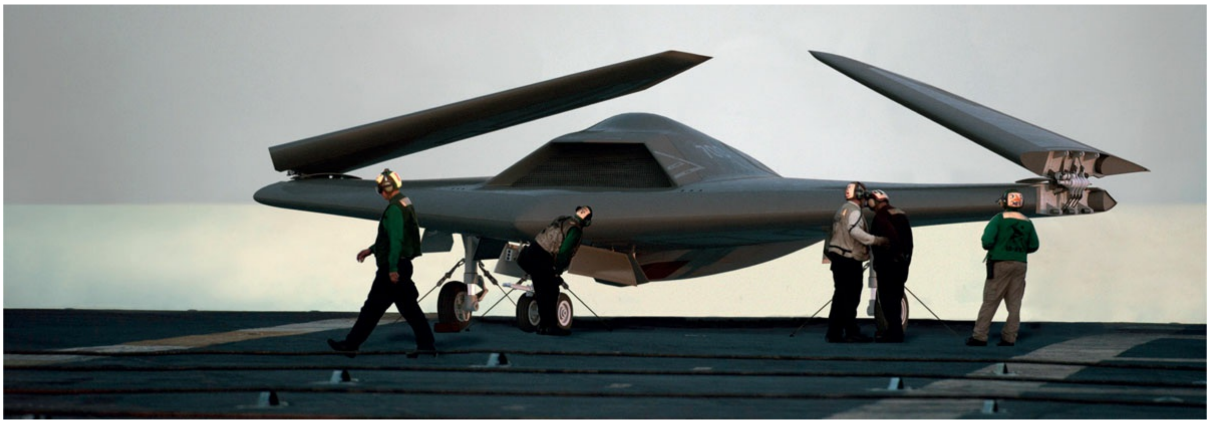
The aircraft is built for autonomous operation, but with oversight from an operator who can intervene if required, which opens up the potential for multiple UAVs to be managed by a single person.

While the contenders are waiting for the Navy to reveal exactly what it wants for UCLASS, from what the Secretary of the Navy Ray Mabus told journalists after his address at the US Naval Academy on 27 May 2011, it seems there may also be an element of the Navy waiting to see what industry can provide.

Whatever eventual route the UCLASS program follows, and irrespective of whether this particular UAV incarnation has the penetrating heavy strike capacity some have called for, the stakes are very high. In April 2015, at the Navy League's Sea-Air-Space Exposition, Mabus predicted that the Lockheed Martin F-35 Lighting II will almost certainly be the Navy's last ever piloted strike fighter, which would mean the F/A-XX Boeing F/A-18E/F Super Hornet's replacement being unmanned.

As Mabus said, "We're looking at future UCLASS systems to be the bridge between manned systems and completely autonomous unmanned strike, which will be sometime in the 2020s, to develop that program using UCLASS to get us there" – and there is a lot riding on getting that right.

An artist's rendering of the unmanned (K)RQ-25 Sea Ghost as it shows an F-35C being refueled via the US Navy's "hose and reel" type of in-flight refueling. (Lockheed Martin)



The Skunk Works' full-scale RQ-25 Sea Ghost is shown on the stern of the flight deck of a US Navy CVN nuclear powered aircraft carrier. (Lockheed Martin)

An artist's rendering of the RQ-25 Sea Ghost as it parallels the coast of Southern California. (Lockheed Martin)

NAVY
721
721

Simulated launch of the Lockheed Martin RQ-25. The Sea Ghost draws on years of operation in a sister UAV, the CIA's RQ-170 Sentinel – aka the "Beast of Kandahar" – the "stealth" candidate for the late 1980s Advanced Cruise Missile codenamed Senior Prom, which resembles the F-117A, and other still classified unmanned systems. (Lockheed Martin)

An artist's impression of the (K)RQ-25 Sea Ghost as it catches the third wire on a US Navy CVN class aircraft carrier. (Lockheed Martin)

X-59 QUESST

2016

PROGRAM: X-59

Name: QueSST

Mission: Low boom supersonic test bed

Length: 96ft 8in (29.46m)

Wing Span: 29ft 6in (8.99m)

Height: 14ft (4.27m)

Max T.O. Weight: 24,300lb (11,023kg)

First Flight: Planned 2021 to early 2022

Last Flight: N/A

Crew: 1

Number Built: 1

Power Plant: 1 x General Electric F414-GE-100

Design Speed: Mach 1.4 (1,074.2mph; 1,728.8km/h)

Service Ceiling: 43,000ft (13,106.4m)

Combat Radius: N/A

Weapons Load: Test equipment payload – maximum 600lb (272.2kg)

In partnership with NASA, the Lockheed Martin Skunk Works team is solving one of the most persistent challenges of supersonic flight: the sonic boom. The airplane to do this is NASA's X-59 QueSST (short for Quiet Supersonic Technology), an experimental piloted aircraft designed to fly faster than sound without producing the annoying sonic booms of previous supersonic aircraft. The X-59 is designed to cruise at 55,000ft at a speed of about 940mph and create a sound about as loud as a car door closing.

Lockheed Martin Skunk Works was selected for the design, build and flight-test of the Low-Boom Flight Demonstrator (LBFD), X-59, in February 2016. The X-59 aircraft will collect community response data on the acceptability of the quiet sonic boom generated by the design, helping NASA establish an acceptable commercial supersonic noise standard to overturn current regulations banning supersonic travel over land. This would open the door to an entirely new global market for aircraft manufacturers, enabling passengers to travel anywhere in the world in half the time it takes today.

Now that legacy of developing low boom supersonic aircraft continues as the company assembles the X-59 for NASA in Palmdale, where, for the first time since the initial machined parts were delivered in November 2018, workers can see the familiar outline of an airplane forming.

And with the recent completion of a major project milestone, known as the Critical Design Review, or CDR, in mid-September 2011, the X-59 is rapidly accelerating its evolution from an airplane on paper toward an airplane ready to roll out of the factory and take flight.

The CDR showed NASA and Lockheed Martin that the design was mature enough to continue into the next phase and essentially finish the assembly. The next milestone will come when an independent review board will present their findings from the CDR.

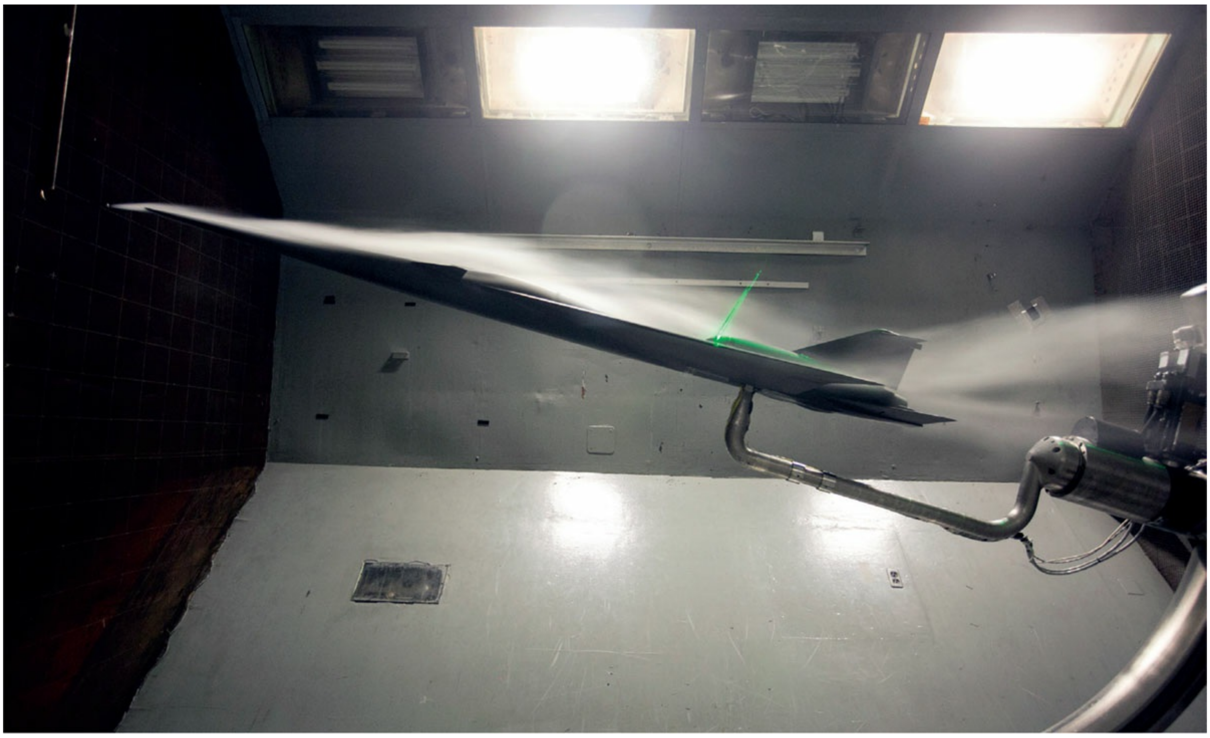
NASA reviewed the CDR, presented any findings or issues that needed to be addressed and then made recommendation as to whether Lockheed Martin should proceed with the project. Based on the results from the CDR, no show-stopping issues were identified and the pace of assembly work on the X-59 is already ramping up.

Perhaps it is only fitting that the future of commercial supersonic aviation in the form of the X-59 is being built by the company responsible for the fastest airplane in history, the SR-71 Blackbird, using innovative production processes that go back 76 years.

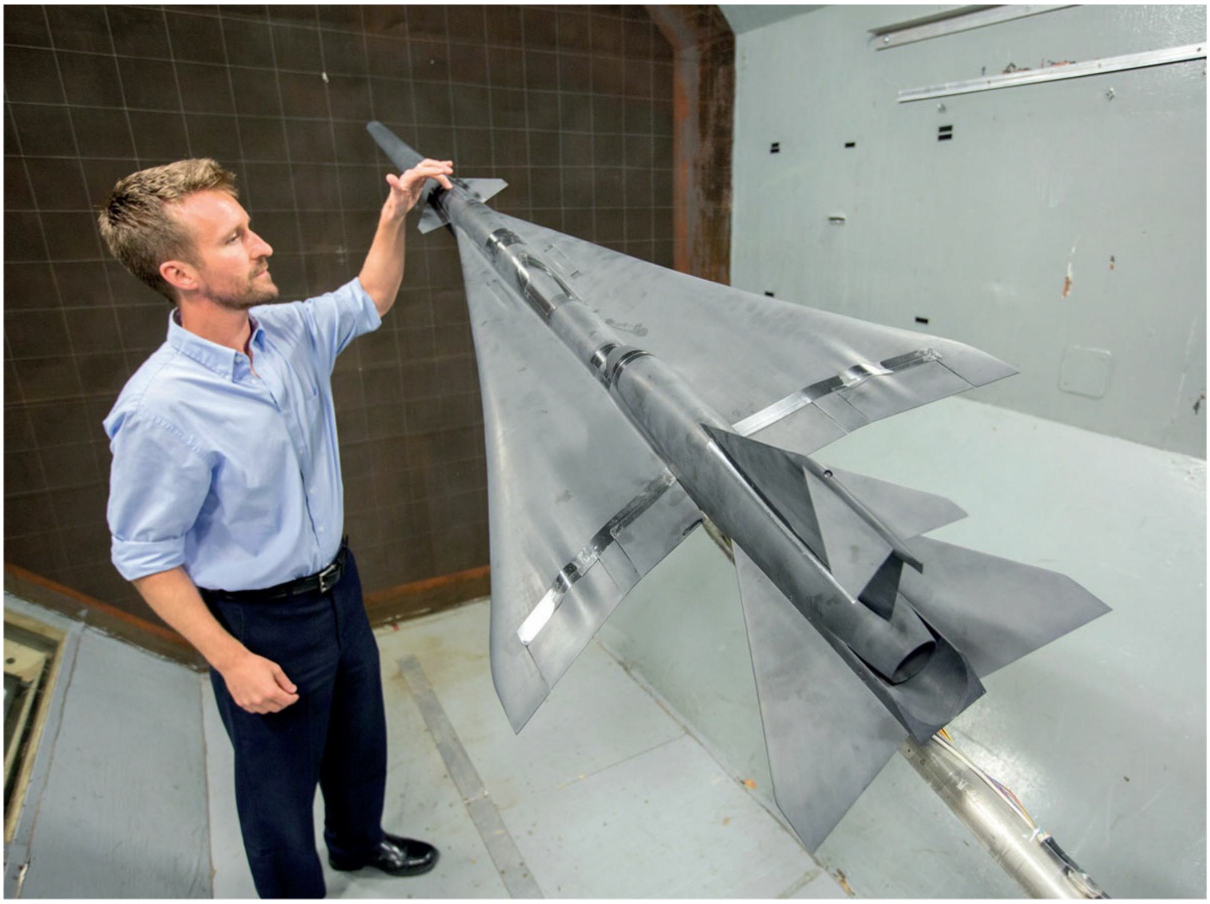
The purpose of Lockheed building the X-59 at the Skunk Works isn't really to pioneer new manufacturing technologies. It's to use what they know works well to get the airplane built and flying for the customer.

The X-59 assembly work taking place on the Lockheed Martin production floor is concentrated within three major sections of tooling. The forward jig is home to the X-59's fuselage, the center section to the airplane's single-piece wing, and the rear jig is set up for the fabrication of the airplane's tail holding the vertical fin and the horizontal stabilizer – a section also known as the empennage.

Initial flight-tests to ensure that the vehicle is operating well in 2021 will be followed by a series of supersonic flights to validate if it is producing quieter sonic booms as expected. After that, the X-59 will begin its community overflights to gather public response data, with the plan to present that information to the FAA and others in 2023.



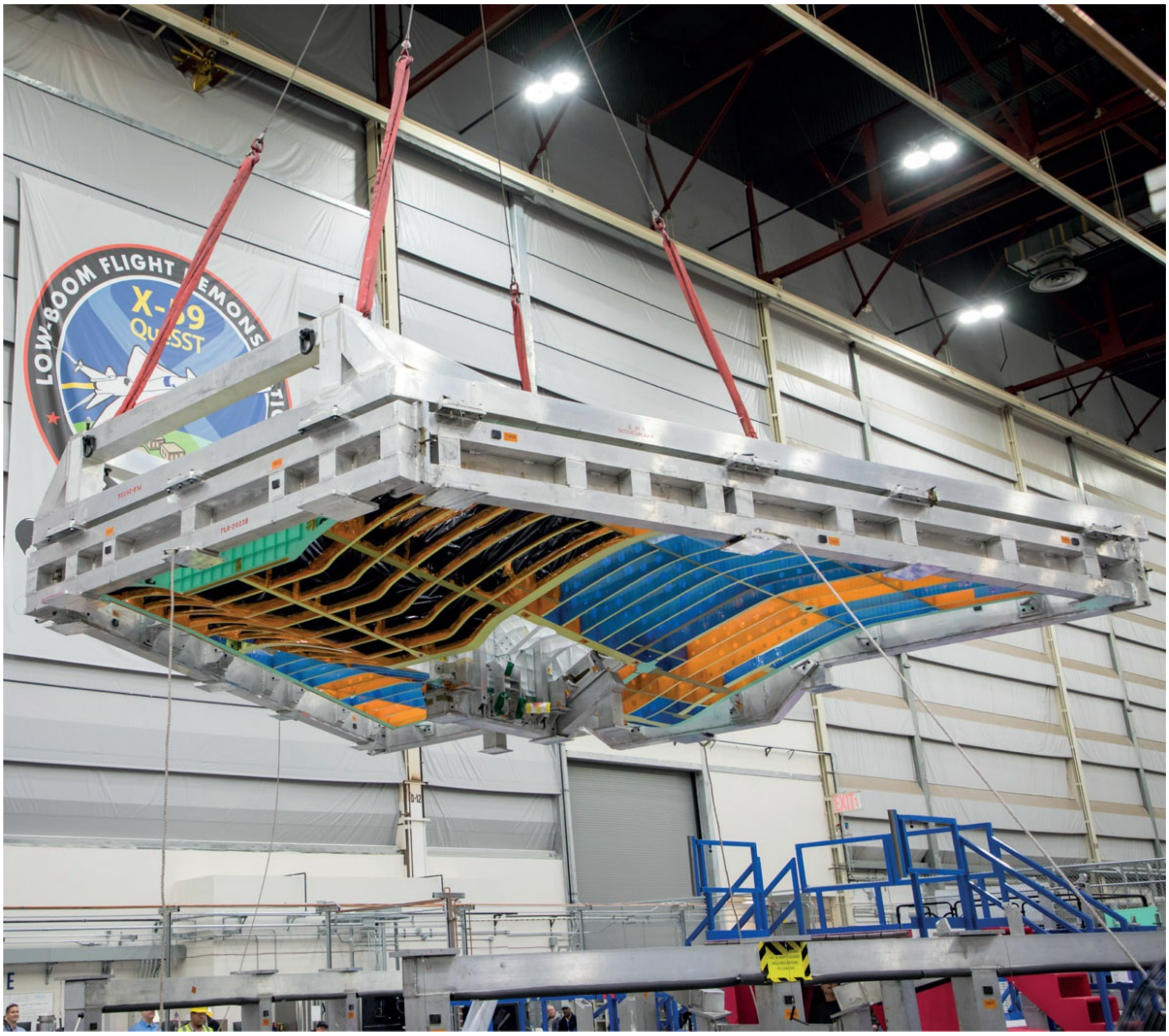
A sub-scale model of the X-59 goes through smoke/laser airflow evaluation in the 14 x 22ft subsonic tunnel at NASA Langley Research Center. This sort of testing gives you a real experimental grounding to see how it compares to the analytical methods. (NASA)



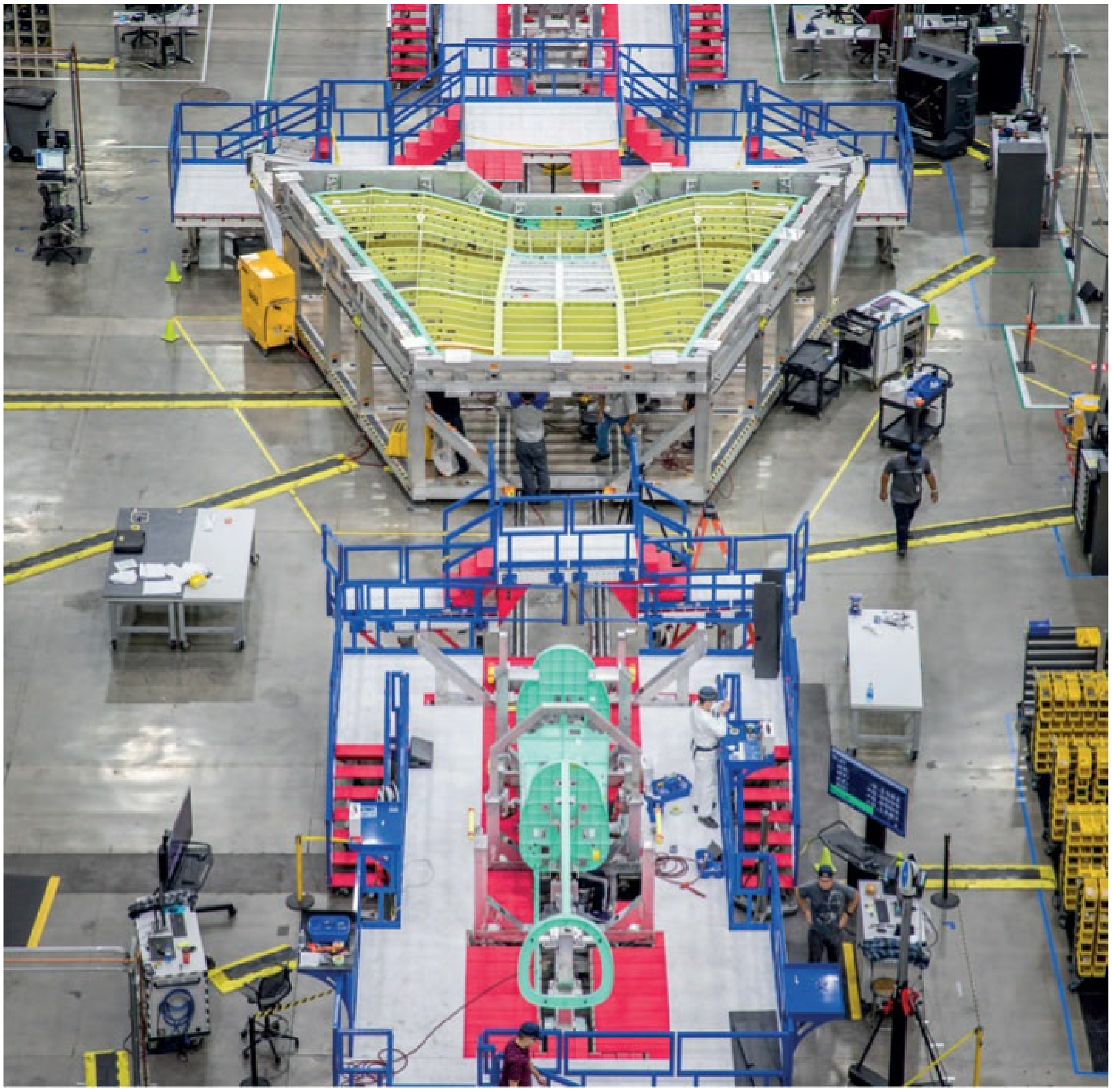
A NASA researcher inspects an 8 percent scale model of the X-59 in NASA Langley's 12ft low-speed tunnel in Hampton, VA. (NASA)

The X-59 QueSST 9.5 percent scale model was tested at Mach numbers from 0.3 to 1.55 in the 8 × 6ft supersonic wind tunnel at NASA's Glenn Research Center in Cleveland. (NASA)

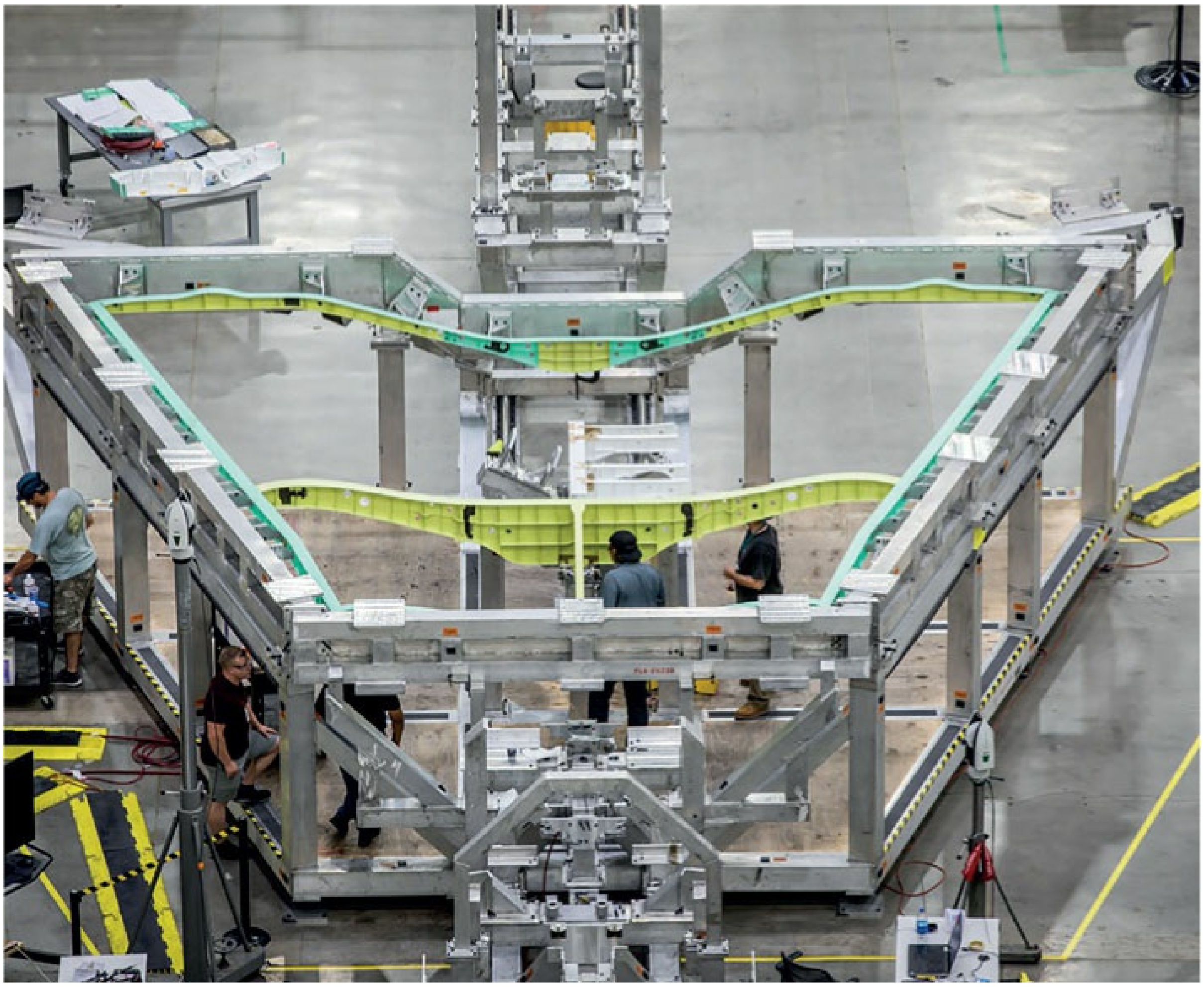
A test engineer for Jacobs Technology Inc., finalizes the set-up of the Quiet Supersonic Technology (QueSST) preliminary design model inside the 14 x 22ft subsonic tunnel at NASA Langley Research Center. (NASA)


LOW-BOOM FLIGHT DEMONS
X-59
QueSST

The X-59 QueSST wing assembly is lifted by a crane and moved to another area of the manufacturing floor in preparation for wing skin installation. The general shape of NASA's X-59 QueSST airplane, including parts of its wing, can be seen in this overhead view. (Lockheed Martin)



Construction and assembly of the supersonic X-59 QueSST research airplane at Lockheed Martin's Skunk Works saw much progress during 2019. In this view, the forward fuselage and cockpit begin to take shape. (Lockheed Martin)



The first wing and aft fuselage parts are secured in the assembly structure as the construction of the X-59A QueSST. (Lockheed Martin)

859
NASA
X-59 QueSST

NASA
X-59 QueSST
MASTER CAUTION

This artist's concept of NASA's QueSST jet reflects the airplane's final configuration following years of research and design engineering. The jet is now under construction by Lockheed Martin at the company's Skunk Works facility in Palmdale. In what's said to be a "significant milestone" for supersonic passenger flight, NASA has completed the preliminary design review of its low-boom X-plane. Experts from NASA and Lockheed Martin say the QueSST design could reduce the sonic boom to a "thump." (Lockheed Martin)

859
NASA
X-59 QueSST
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Researchers at NASA's Langley Research Center in Hampton successfully completed in-flight testing of the XVS technology on NASA's Beechcraft King Air UC-12B. The XVS will give X-59 pilots the confidence they need to safely maneuver the skies without a forward-facing window. (NASA)

COMPACT FUSION

2019

More than 50 years ago, nuclear power through fission was the excitement of its day. People tried using it to power almost everything, even planes. In the end, operational hurdles prevented fission from widespread use. While fission continues to power our nuclear reactors today, fusion offers a cleaner, safer source of energy.

Fusion is the process by which a gas is heated up and separated into its ions and electrons. When the ions get hot enough, they can overcome their mutual repulsion and collide, fusing together. When this happens, they release a lot of energy – about one million times more powerful than a chemical reaction and three to four times more powerful than a fission reaction. Nuclear fusion is the process by which the sun works. Lockheed Martin is creating a concept that will mimic that process using a magnetic bottle. The bottle is able to handle extremely hot temperatures, reaching hundreds of millions of degrees. By containing this reaction, it can release energy in a controlled fashion to create power that can be used.

A reactor small enough to fit on a truck could provide enough power for a small city of up to 100,000 people. Building on more than 60 years of fusion research, the Lockheed Martin Skunk Works approach to compact fusion is a high beta concept. This concept uses a high fraction of the magnetic field pressure, or all of its potential, so Lockheed Martin can make the devices ten times smaller than previous concepts. That means that Lockheed Martin can replace a device that must be housed in a large building with one that can fit on the back of a truck.

The compact size is the reason it is believed that it will be able to create fusion technology quickly. The smaller the size of the device, the easier it is to build up momentum and develop it faster. Instead of taking five years to design and build a concept, it takes only a few months. So, allowing for a number of these testing and refinement cycles, it shoud be possible to develop a prototype within a five-year timespan.

The heat energy created using this compact fusion reactor will drive turbine generators by replacing the combustion chambers with simple heat exchangers. In turn, the turbines will then generate electricity or the propulsive power for a number of applications. Rapid design cycles allow for less conservative design choices, faster consideration of alternatives, less capital and the ability to maintain momentum moving forward with constant progress. Lockheed Martin believe that compact fusion could:

- Provide aircraft with unlimited range and unmatched endurance. Thanks to the compact fusion's high energy density, a C-5 would be able to fly for a year on a few bottles of hydrogen.
- Deliver energy to the developing world. To provide the world with an unlimited supply of economical energy.
- Provide safe power for safe seas. Through the use of turbine generators, compact fusion could produce electricity to propel a ship, delivering an unlimited range capability at sea.
- Speed up space travel. Thanks to the high-energy density of the compact fusion reactor, it would be possible to fly to Mars in just one month versus six months today.
- Power a city of 50,000–100,000 people. By modifying current modular 100-megawatt-class gas turbine plants to run on fusion power, they could be deployed to areas around the world as needed.
- Make clean water available to the masses. Compact fusion would reduce the cost of desalination by over 60 percent. This would bring clean drinking water to the world.

In 2017, a Lockheed Martin spokesperson commented that within ten years it would invent a small nuclear fusion engine capable of powering a large oceangoing vessel or a small town with infinite amounts of clean nuclear power. Ten more years would see Lockheed commercialize free-standing cold fusion reactors to provide “safe,” nuclear “proliferation-free,” greenhouse gas emission-free “clean power for the world.”

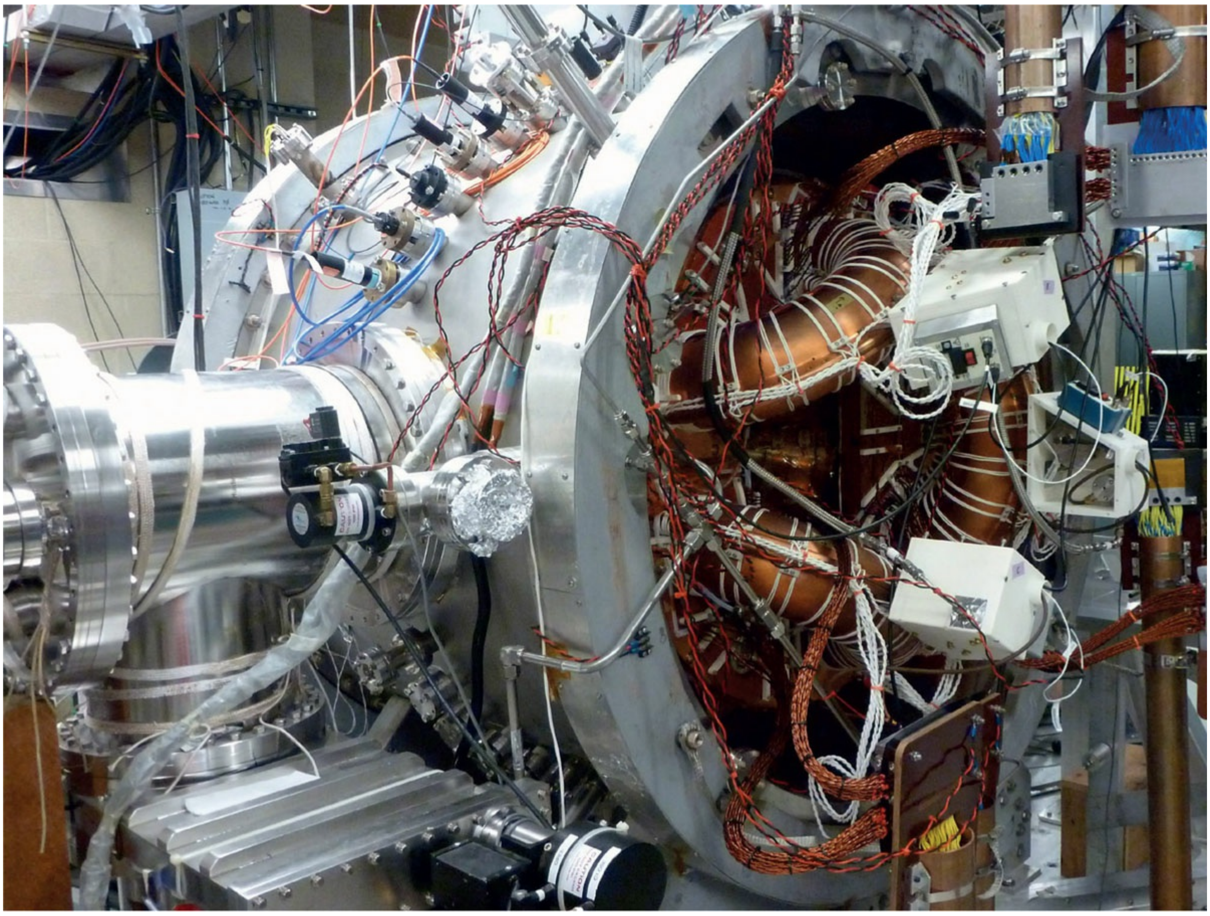
“Progress has been slower than hoped.” That being said, Skunk Work’s Vice President and General Manager, Jeff Babione, remains optimistic: “We still have confidence that the company will eventually succeed in developing a working cold fusion nuclear reactor”, he says. In fact, Lockheed hoped to progress to its next iteration – T5 – before the end of 2019, but the onset of the COVID-19 pandemic has moved the T5 iteration out into 2021.

The T5 reactor will be used principally to show the heating and inflation of the plasma, as well as measure the depth of the trapped magnetized sheath protecting the walls from the plasma. It will also help measure the losses associated with where the boundaries of the magnetic field lines containing the plasma intersect or wrap around stalks holding the reactor’s superconducting magnets. In particular, T5 will be used to demonstrate the high-density plasma source and the ability to capture and confine the neutral beam injectors which initiate the plasma ignition.

Beyond the next reactor, Lockheed plans a further three test units, culminating in T8, which will demonstrate a deuterium-tritium ignited reactor showing full confinement and stability of the alpha particles produced by the fusion process.

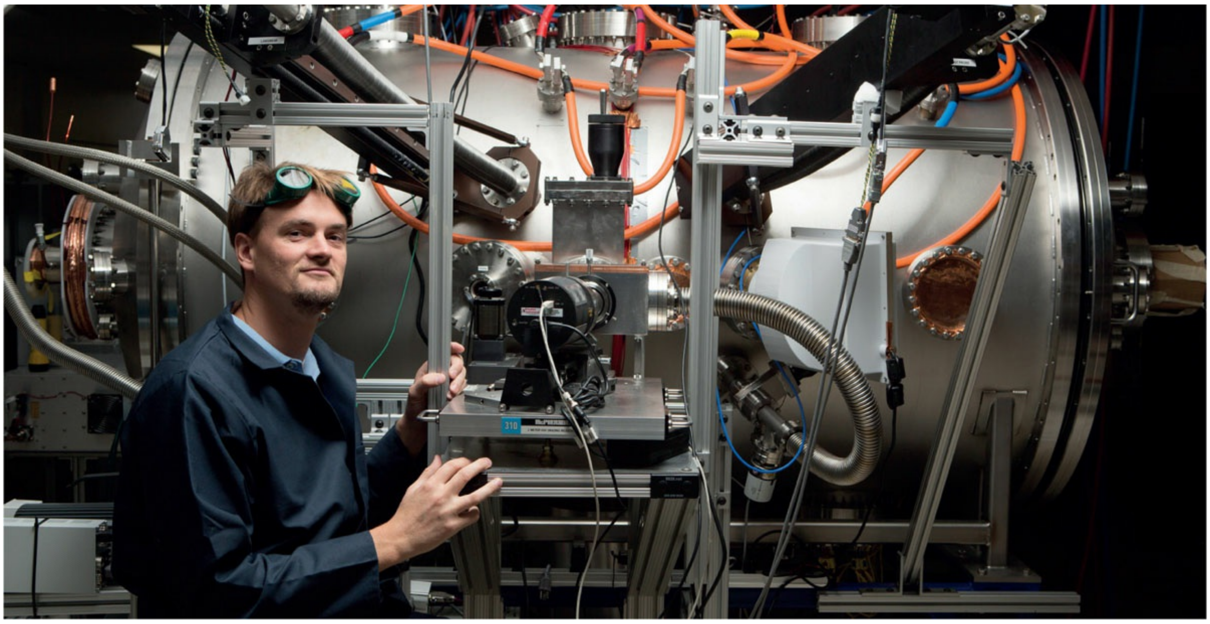
According to Babione: “The next challenge is to scale it. How do you scale it up to generate power for a city or an entire town? That’s all ahead of us. It’s certainly not easy but we think it is in the realm of the possible.”

The compact size is the reason that the team at the Lockheed Martin Skunk Works is focused in its quest to develop fusion technology quickly. The smaller the size of the device, the easier it is to build up momentum and develop it faster. Instead of taking five years to design and build a concept, it takes only a few months. Lockheed Martin feels it will be able to develop a prototype within a five-year timespan. (Lockheed Martin)



A reactor small enough to fit on a truck could provide enough power for a small city of up to 100,000 people. (Lockheed Martin)

To mimic the energy created by the sun and control it here on Earth, Lockheed Martin is creating a concept that can be contained using a magnetic bottle. The bottle is able to handle extremely hot temperatures, reaching hundreds of millions of degrees. By containing this reaction, the energy can be released in a controlled fashion to create usable electricity that can power a remote austere base, or a small town of up to 80,000 homes. One interesting development is the possibility that the compact fusion reactor could be made small enough to power a manned or unmanned aerial platform. If this comes to fruition, the world could have a fleet of aircraft that could fly anywhere in the world unrefueled with no carbon footprint. (Lockheed Martin)



With this program, the development of a compact fusion reactor the Skunk Works pushes way beyond the limits that are typically associated with the Skunk Works. (Lockheed Martin)

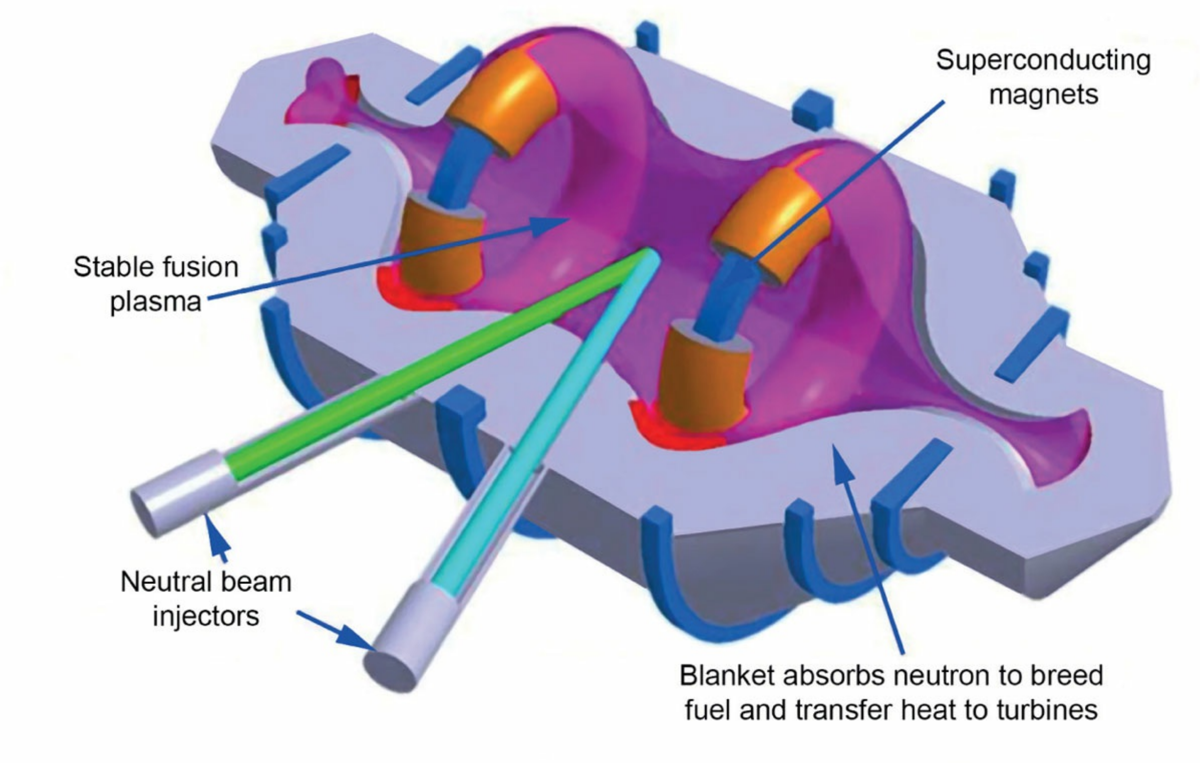

Superconducting magnets
Stable fusion plasma
Neutral beam injectors
Blanket absorbs neutron to breed fuel and transfer heat to turbines

Illustration of the internals of the Lockheed Martin compact fusion reactor and how it can contain the extreme temperatures that are a signature of fusion reaction. (Lockheed Martin)

SR-72

2030

PROGRAM: SR-72

Name: Son of Blackbird

Mission: Strategic reconnaissance

Length: 108ft (32.9m) estimated

Wing Span: 49ft 6in (15.1m) estimated

Height: 13ft 6in (4.1m) estimated

Max T.O. Weight: 140,000lb (63,503kg)

First Flight: 2030 estimated

Last Flight: Unknown

Crew: 2 or optionally unmanned

Number Built: N/A

Power Plant: N/A

Design Speed: Mach 8 (6,138mph; 9,878.4km/h) estimated

Service Ceiling: 180,000ft (54,864m) estimated

Combat Radius: Intercontinental

Weapons Load: Photographic, electronic and anti-denial equipment and

NASA awarded a contract to Lockheed Martin to study the feasibility of building a hypersonic propulsion system for a concept intelligence, surveillance and reconnaissance (ISR) aircraft dubbed the SR-72 using existing turbine engine technologies.

The contract provides for a parametric design study to establish the viability of a turbine-based combined cycle (TBCC) propulsion system consisting of several combinations of near-term turbine engine solutions integrated with a very low-Mach ignition dual-mode ramjet (DMRJ) in the SR-72 vehicle concept.

The SR-72 is envisioned as an unmanned, reusable hypersonic ISR and strike aircraft capable of Mach 6 flight, or nearly double the speed of its predecessor, the SR-71 Blackbird. NASA is funding the validation of a previous Lockheed study that found that speeds up to Mach 7 could be achieved with a dual-mode engine that combines turbine and ramjet technologies.

Skunk Works was responsible for developing the SR-71 Blackbird, which was able to achieve Mach 3.2 with specially designed Pratt & Whitney J58 engines. The power plants were able to function as a low-speed ramjet by redirecting intake air around the engine core and into the afterburner starting at Mach 1.4 to full turboramjet from Mach 2.5 and above.

Potential adversaries are working on technologies to counter USAF fighter and bomber stealth capabilities. The service sees hypersonic vehicles as the next logical step in that arms race.

The USAF has a hypersonics roadmap that envisions fielding a hypersonic strike weapon, to succeed the X-51 Waverider proof-of-concept demonstration. The Waverider successfully launched from a B-52 and was powered to Mach 4.8 by a booster rocket. The X-51 then accelerated to Mach 5.1 after igniting its ramjet engine.

The roadmap envisions a follow-on program calling for a reusable unmanned aircraft with Mach 6 speeds. At that speed, intelligence can be gathered or weapons delivered before enemy air defenses are even alerted.

Both the Air Force Research Laboratory (AFRL) and DARPA have been after a low-speed ramjet for years. The agencies' HTV-3X program demonstrated that a ramjet that could operate below Mach 3. That inspired Lockheed to partner with Aerojet Rocketdyne to develop a way to use off-the shelf engines like the F 100 or F110 for short bursts of acceleration beyond Mach 2.2 in an attempt to close the gap between the two propulsion technologies. This study is to see if the SR-72 technology demonstrator can use existing technologies to create a dual-mode ramjet that in theory can light up at Mach 2 to 2.5. The key to this whole effort is whether they can do it and finding the required technologies so they can plan for a program in which they can develop the program as envisioned.

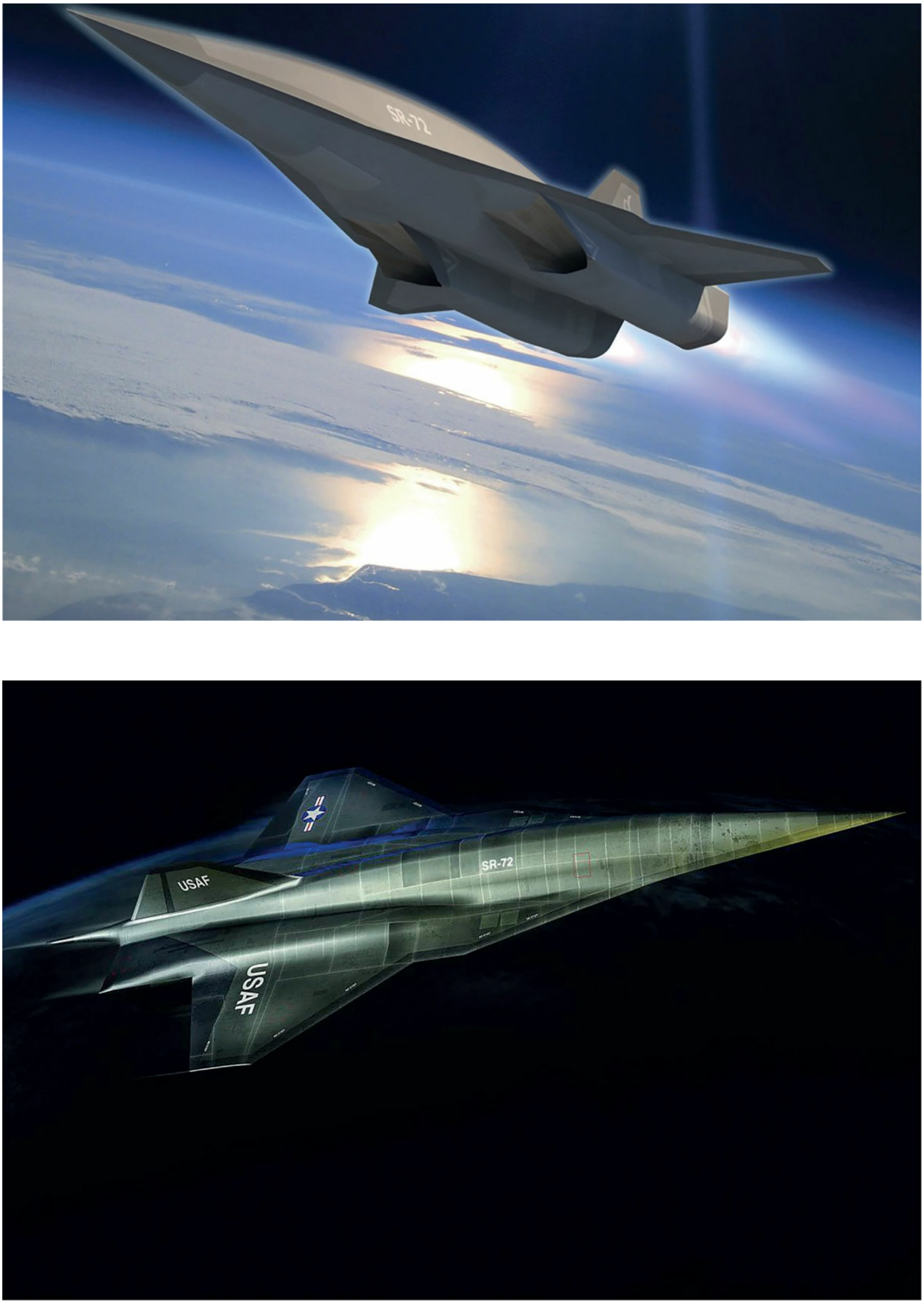
The problem with hypersonic propulsion has always been the gap between the highest-speed capability of a turbojet and the lowest speed of a ramjet. Most ramjets cannot achieve ignition below Mach 4. Turbine engines typically can accelerate to only Mach 2.2, below speeds at which a ramjet could take over and continue acceleration.

Therefore, NASA and Lockheed must develop either a turbine engine that can accelerate to Mach 4 or a ramjet that can function at speeds within a turbine engine's envelope. Design engineers from both Lockheed Martin and NASA are looking for a turbine-based combined system where at low speeds you have a turbine providing power, then at higher speeds a ramjet or scramjet takes over. The target is to be able to go up to Mach 7 then transition back to the turbine to land it on a runway and recover it. The problem is how you can get the vehicle to fly fast enough to ignite the DMRJ and then have the DMRJ take over.

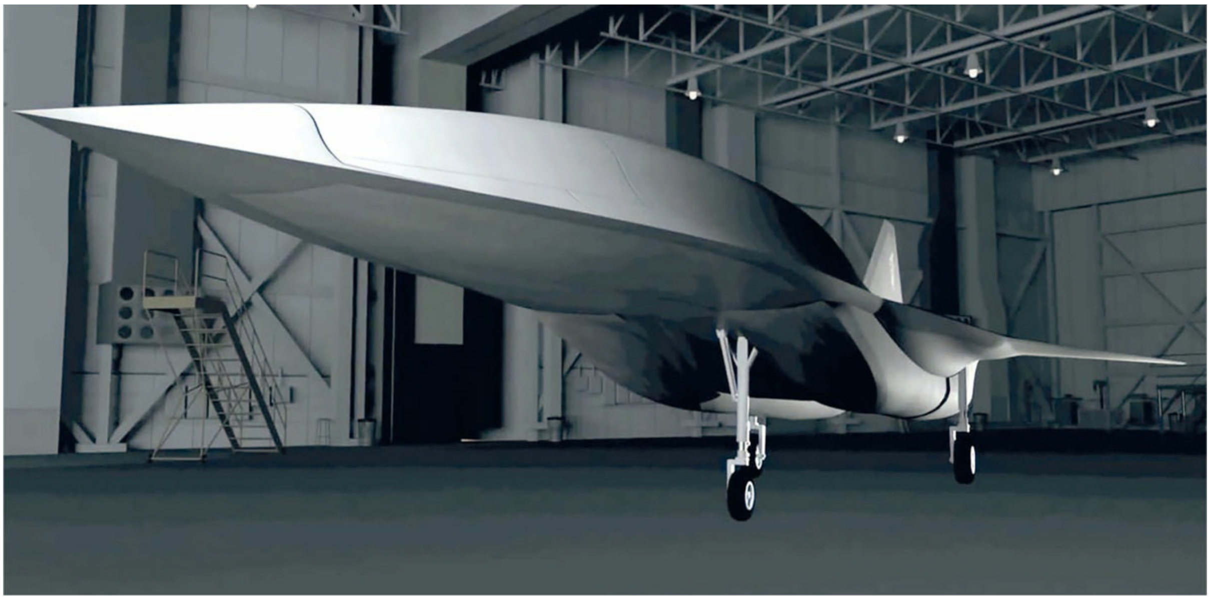
NASA is considering several existing turbofan engines for use in the project, including the Pratt & Whitney F100-PW-229 that powers both the Boeing F-15 and Lockheed Martin F-16, among other aircraft. The General Electric F414 used by the Boeing F/A-18E/F Super Hornet also is being studied, along with the supersonic turbine engine for long range (STELR) engine conceived by AFRL.

If the study is successful, NASA wants to fund a demonstration program. Lockheed Martin would test the dual-mode ramjet in a flight research vehicle, and try to find solutions to issues like engine packaging and designing the thermal management system.

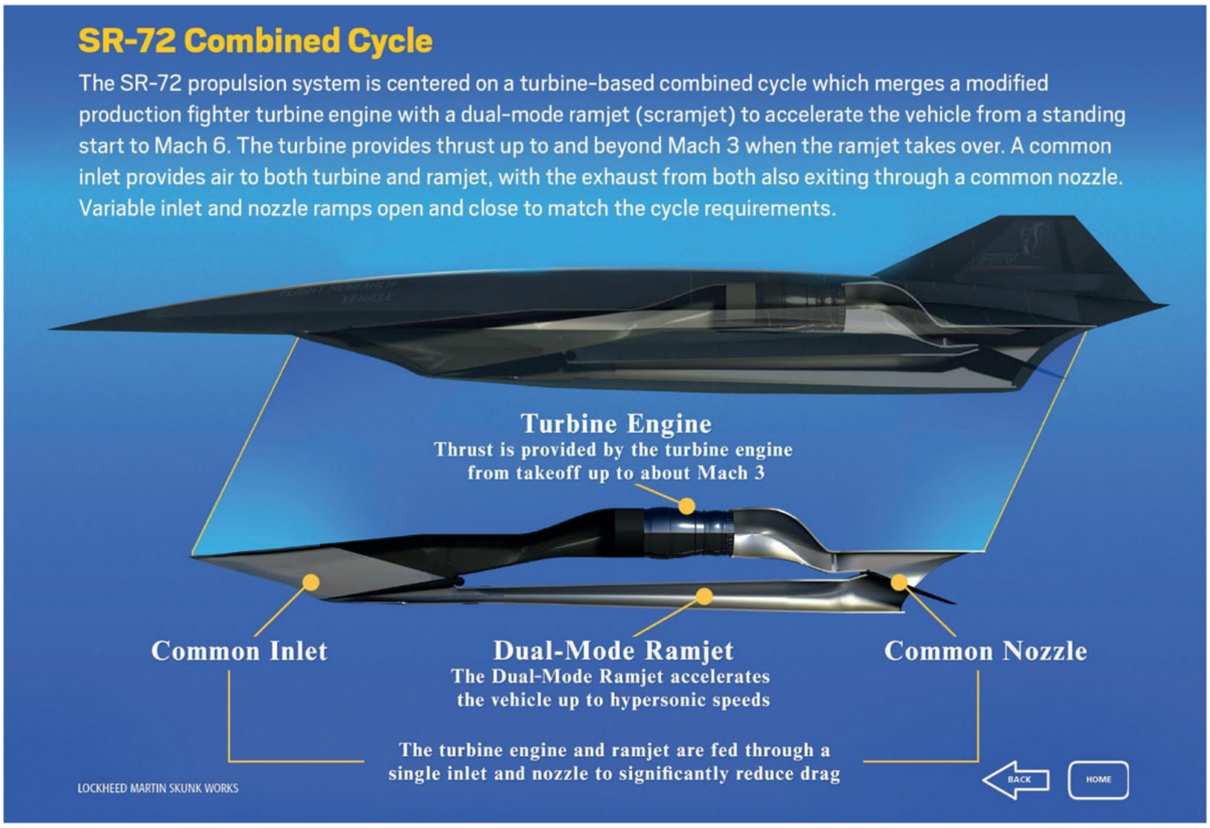
As with all programs being developed in the late 2019/early 2020-time frame, to include the SR-72 program, the COVID-19 pandemic has delayed and, in some cases, canceled programs due to budget cuts and reduced manpower available to this and other critical programs under development.


SR-72
USAF
SR-72
USAF

Three illustrations of what the SR-72 may look like in flight. (Lockheed Martin)



An illustration of the SR-72 on its landing gear in a hangar. (Author's collection)



SR-72 Combined Cycle

The SR-72 propulsion system is centered on a turbine-based combined cycle which merges a modified production fighter turbine engine with a dual-mode ramjet (scramjet) to accelerate the vehicle from a standing start to Mach 6. The turbine provides thrust up to and beyond Mach 3 when the ramjet takes over. A common inlet provides air to both turbine and ramjet, with the exhaust from both also exiting through a common nozzle. Variable inlet and nozzle ramps open and close to match the cycle requirements.

Turbine Engine
Thrust is provided by the turbine engine from takeoff up to about Mach 3

Common Inlet

Dual-Mode Ramjet
The Dual-Mode Ramjet accelerates the vehicle up to hypersonic speeds

Common Nozzle

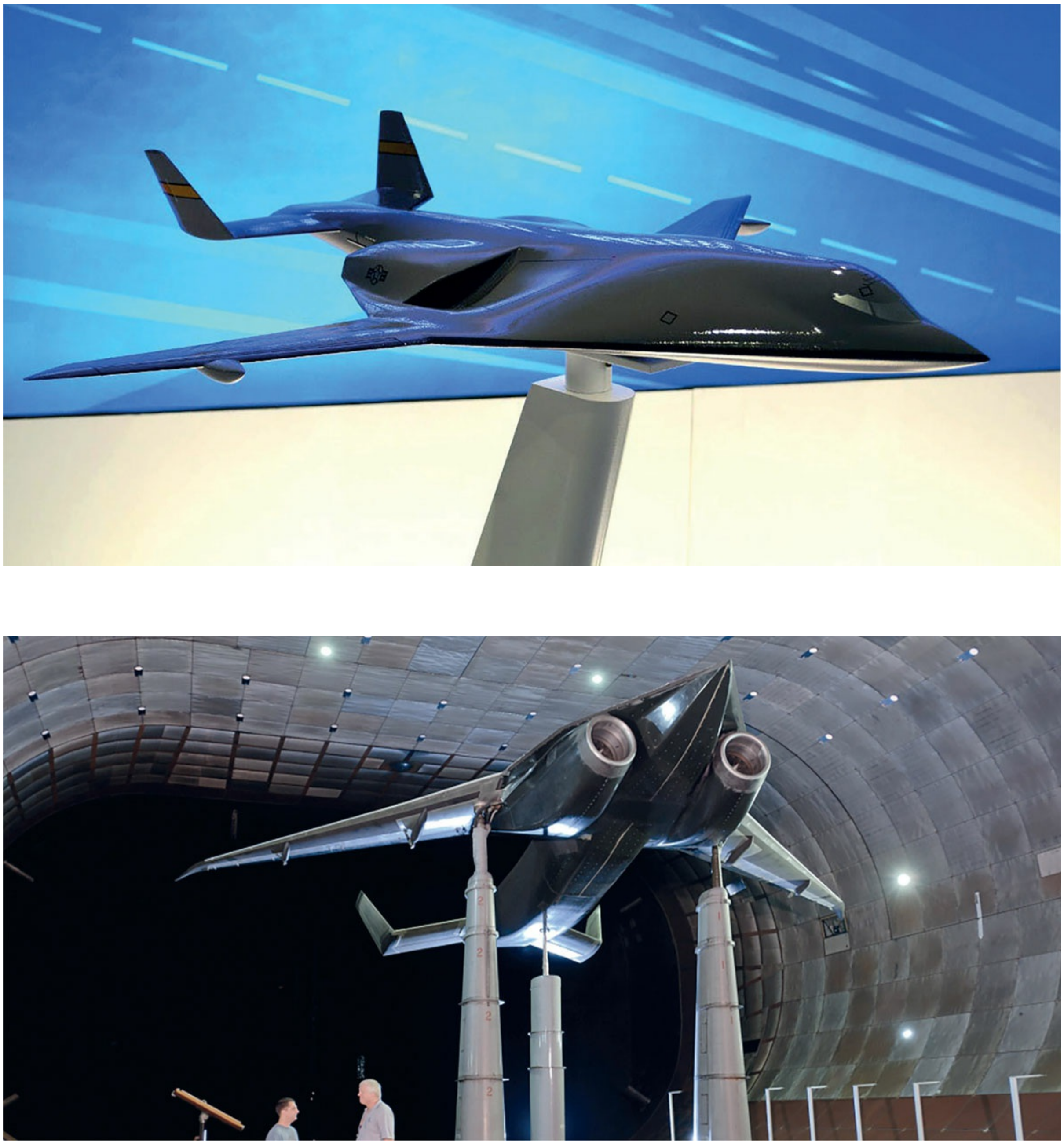
The turbine engine and ramjet are fed through a single inlet and nozzle to significantly reduce drag

LOCKHEED MARTIN SKUNK WORKS

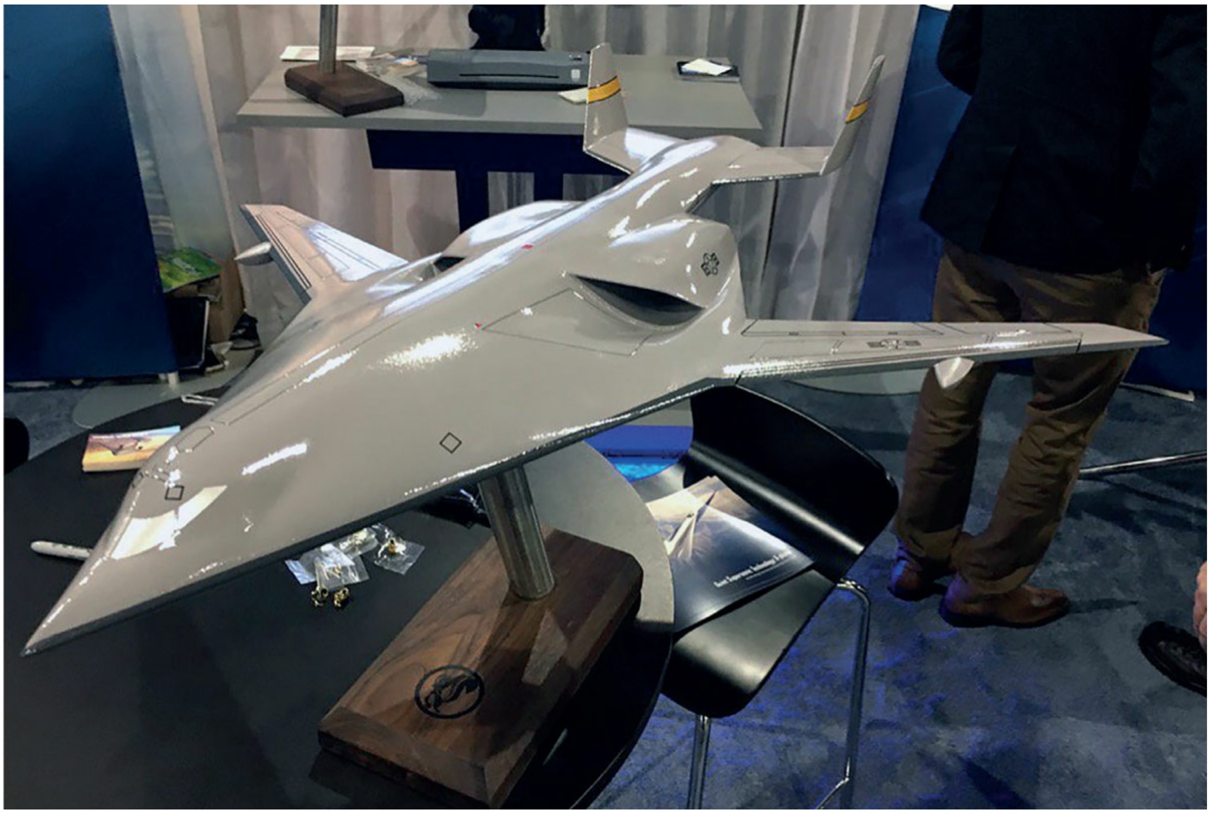
An illustration of the proposed SR-72's propulsion "combined cycle" engine and inlet layout. (Lockheed Martin)

LOCKHEED MARTIN

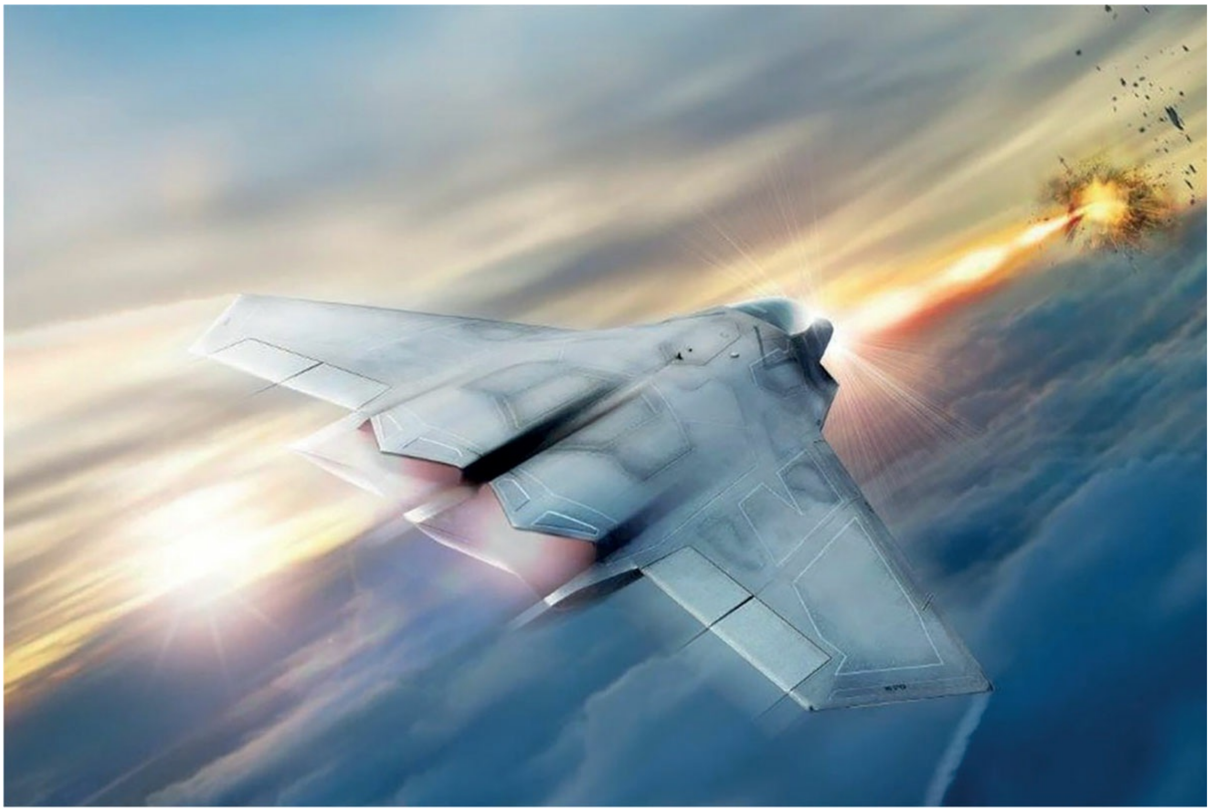
FUTURE THOUGHTS AND PAPER AIRPLANES



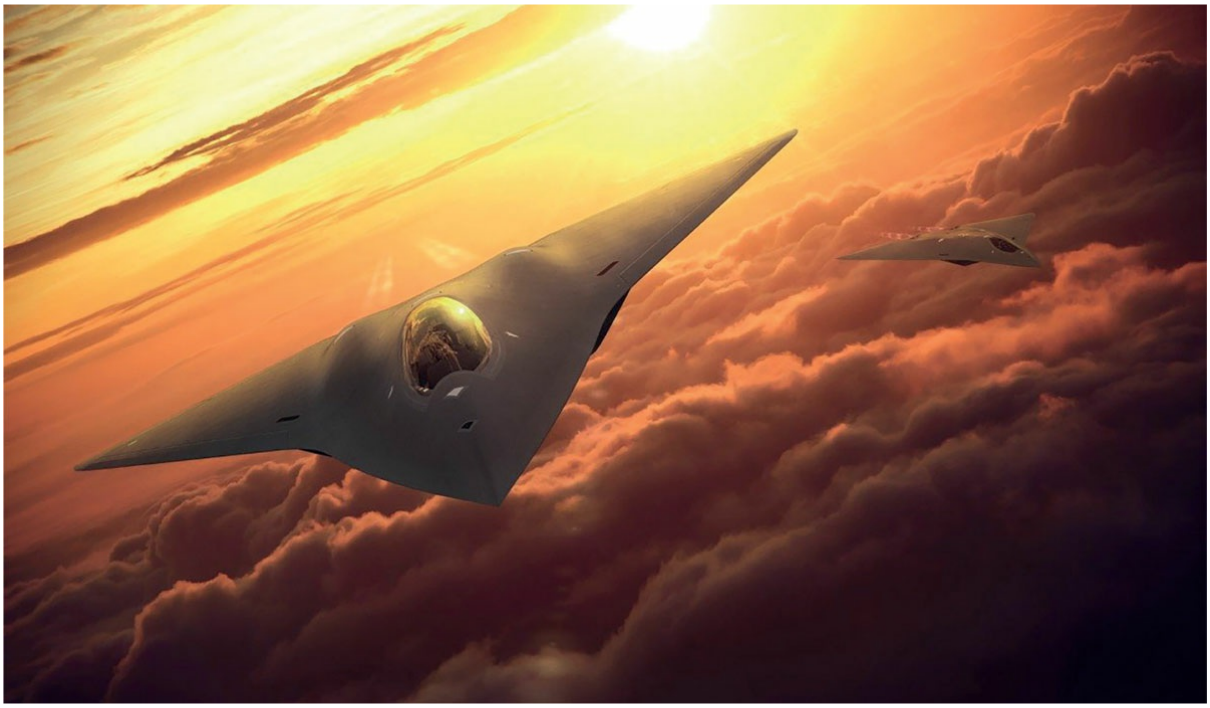
Since 2011, Lockheed Martin has used designs related to their Speed Agile proposals as the basis for stealthy aerial refueling tanker concepts, which are still under development. (Lockheed Martin)



A model of a "hybrid-wing body" (HWB) model presented at a recent aviation conference. (Author's collection)



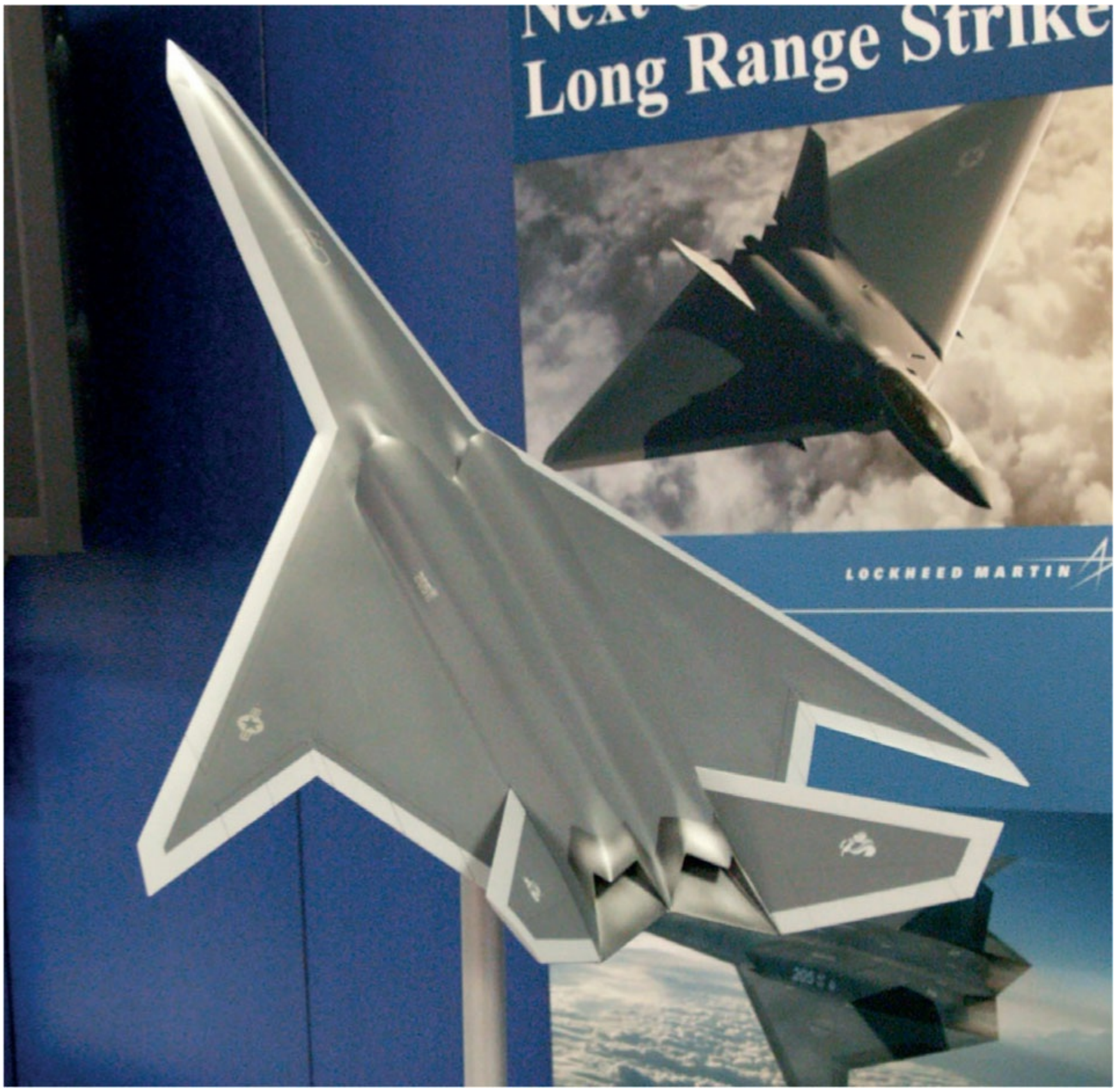
The rear view of a tailless fighter with thrust vectoring successfully taking out an enemy drone. (Lockheed Martin)



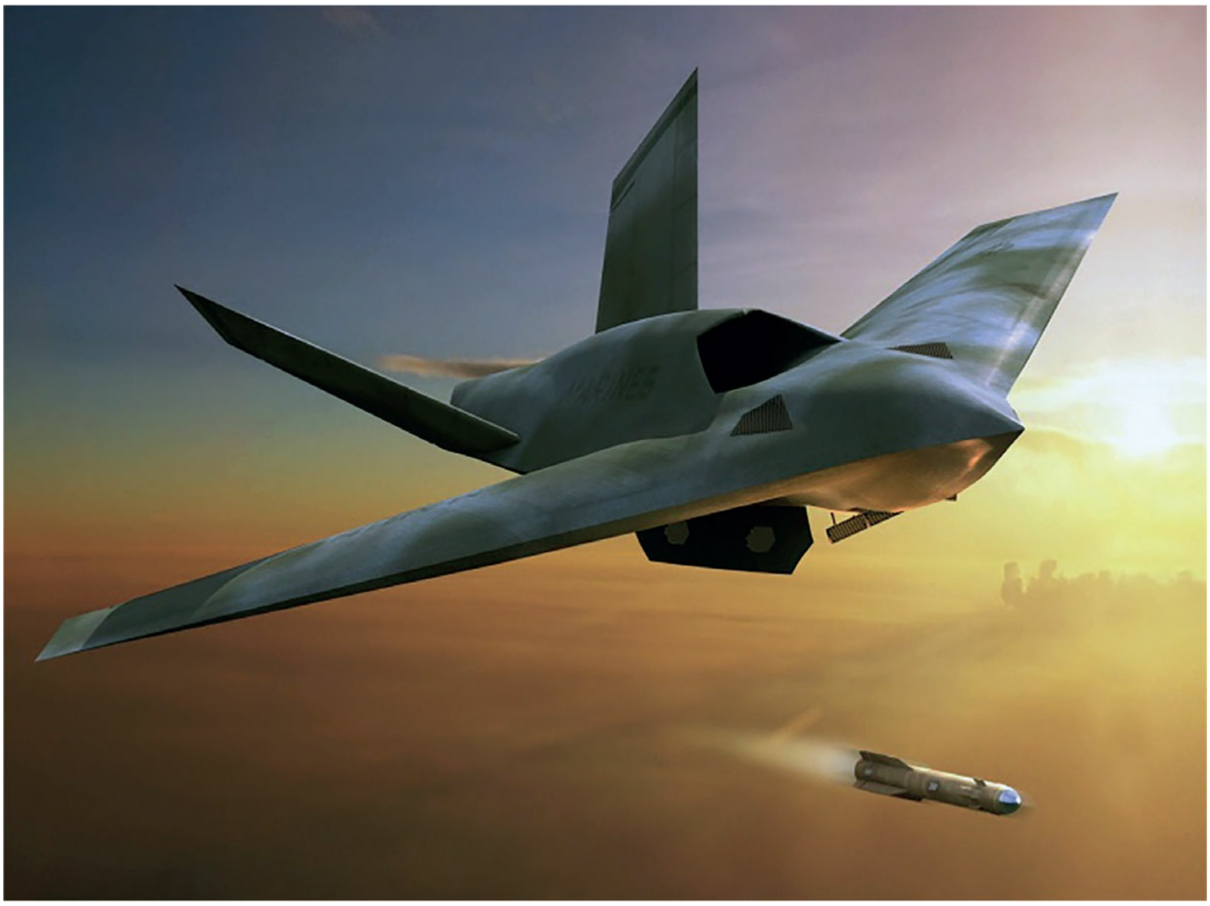
More reminiscent of the failed GD/FW-MacAir A-12 "Avenger II" is one of several tailless "sixth-generation" fighters. (Lockheed Martin)

An earlier Skunk Works design for the next-generation fighter. (Lockheed Martin)

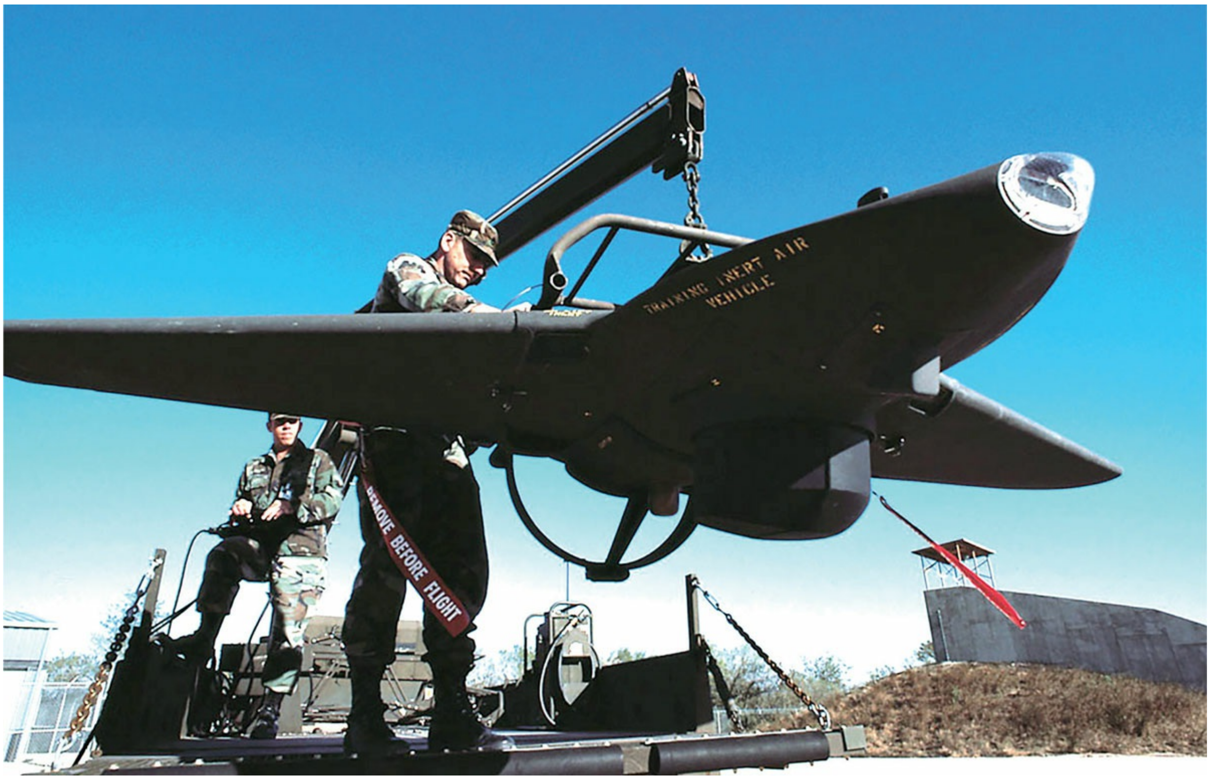
Even the Lockheed Martin F-35A is a candidate to go pilotless in the near future as seen in this illustration. (Lockheed Martin)


Long Range Strike
LOCKHEED MARTIN

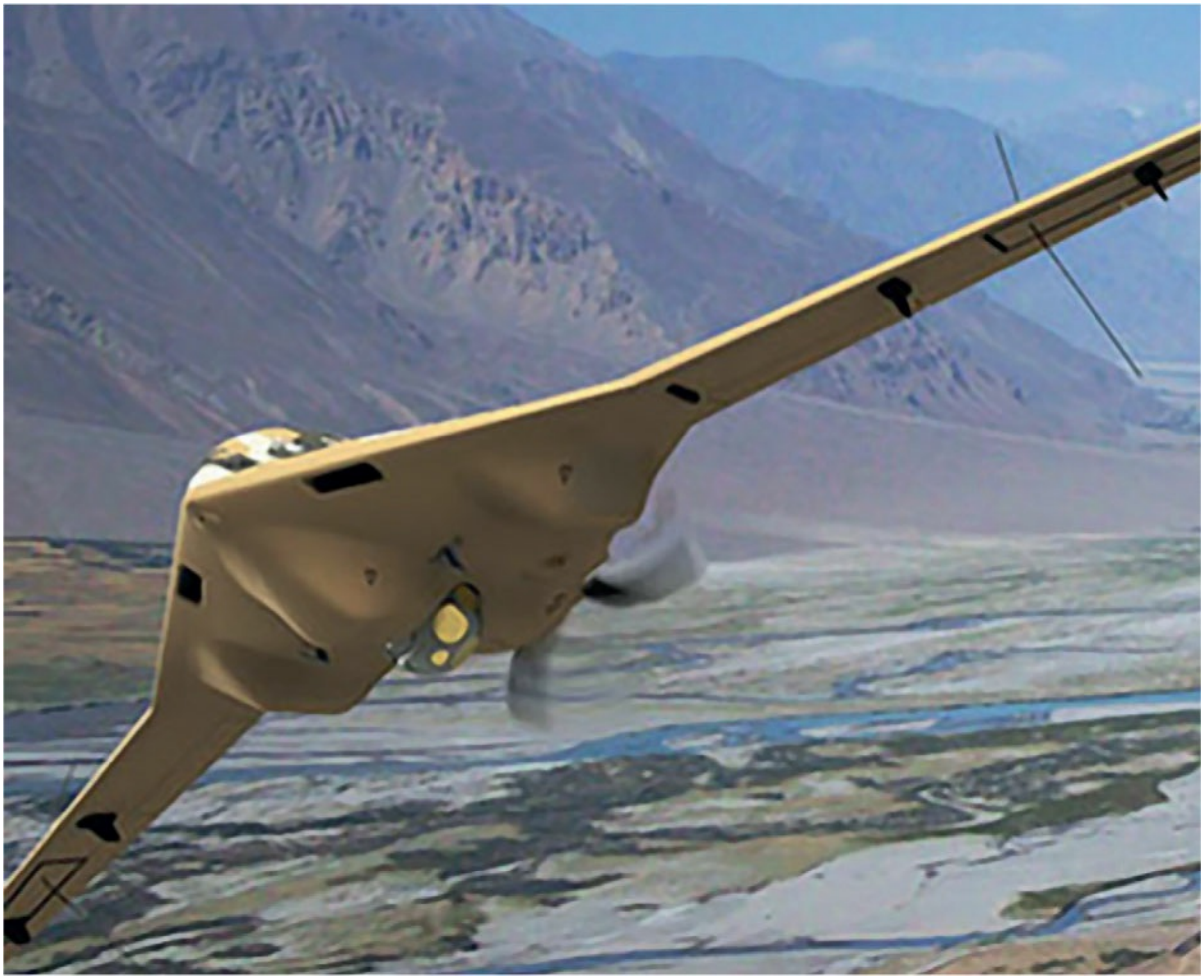
A scale model of one of the Lockheed Skunk Works' concepts of the "next-generation long range strike" manned or unmanned bomber. (Lockheed Martin)



Another artist's rendering of an unmanned tactical aircraft firing an air-to-ground weapon during a "suppression of enemy air defenses" (SEAD) mission with a family resemblance to the U-2X. (Lockheed Martin)


TRAINING INERT AIR VEHICLE
REMOVE BEFORE FLIGHT

Some ideas were developed before their time as with the US Army's Aquila RPV drone developed in the early 1980s before computerization took hold of the aerospace community. The US Army never did deploy the Aquila and all engineering and production tooling were given to the Israelis. With lessons learned, the Lockheed Martin 21st-century version of the Aquila bears a striking resemblance to its 40-year-old design. (US Army)



The 21st-century version of the Aquila is highlighted in these three artist's renderings. (Lockheed Martin)

SKUNK WORKS LEADERSHIP BIOGRAPHIES

KELLY JOHNSON (1943–75)

FOUNDER AND CHIEF DESIGN ENGINEER

Clarence Leonard “Kelly” Johnson, renowned founder of Lockheed Martin Skunk Works and designer of the world’s fastest and highest-flying aircraft, shepherded some 40 military and civilian aircraft into production during his 42+ years with Lockheed.

He joined Lockheed in Burbank in 1933 as a tool designer, and five years later he was named the company’s chief research engineer. He became chief engineer in 1952 and corporate vice president-research and development in 1956.

His design accomplishments range from designing the twin-boomed P-38 Lightning, perhaps the most famed fighter of World War II, to leading design aspects of famed aircraft including the record-setting F-104 Starfighter, the U-2 and the SR-71 Blackbird, the world’s fastest aircraft.

He was known for his hard adherence to his principles including his famous 14 rules and his motto “Be quick, be quiet, be on time.”

Johnson received more than 40 aircraft design and achievement awards and honors, including two Collier Trophies, the Wright Brothers Memorial Trophy, the Medal of Freedom and the National Medal of Technology. Johnson was enshrined in the National Aviation Hall of Fame in 1974.

Johnson was born in Ishpeming, Michigan, on 27 February 1910, the son of struggling Swedish immigrants. He earned a bachelor's and master's degree in aeronautical engineering from the University of Michigan. He knew he wanted to design airplanes from the age of 12 and even declined the position of company president an unprecedented three times in order to continue overseeing the Skunk Works, where he remained a senior advisor even after his formal retirement.

BEN RICH (1975–84, 1986–91)

LONG-TIME ADVANCED DEVELOPMENT PROJECTS DEPUTY

Ben R. Rich, known as "The Father of Stealth," achieved international acclaim for innovative aircraft design, development and production during a 40-year career at Lockheed Martin Corporation.

Rich Joined Lockheed in 1950 and participated in programs such as the F-104, U-2, YF-12 and SR-71. He also led Lockheed's development of the world's first operational stealth aircraft, the F-117A Nighthawk, which would go on to win a Collier Trophy for the most significant achievement in American aerospace in 1989.

He was named senior engineer for Lockheed advanced programs in 1963 and served as Advanced Development Projects program manager and assistant chief engineer until becoming vice president for fighter programs and preliminary design in 1972.

Rich was a fellow of the American Institute of Aeronautics and Astronautics and won its national aircraft design award. He was also a fellow of the Institute for the Advancement of Engineering and a member of the Tau Beta Pi, the honorary professional engineering society.

Rich was born in Manila, Philippine Islands, on 18 June 1925. He received his Bachelor of Science degree in mechanical engineering from the University of California at Berkeley and his master's degree in the same discipline from the University of California, Los Angeles. He graduated from Harvard University's advanced management program in 1968.

He headed the Skunk Works until his retirement in 1991 and received the Pentagon's highest civilian award in 1994: the Distinguished Service Medal.

Prior to his passing in 1995, he served on several government Intelligence committees and published, with Leo Janot, the book *Skunk Works: A Personal Memoir of My Years at Lockheed.*

DICK HEPPE (1984)

R. Richard Heppe joined Lockheed in 1947 and was involved in the conception and development of every new airplane proposed or produced by the Lockheed-California Company leading up to his presidency in 1984.

Heppe was named vice president and general manager of government programs for the Lockheed-California Company (not the Skunk Works) in 1974, vice president of operations in 1979, presidential and vice president and general manager of Advanced Development Projects in 1984.

He published numerous papers in his fields of expertise. He was a member and chairman of several research advisory committees for the National Advisory Committee for Aeronautics (NACA) and the National Aeronautics and Space Administration (NASA). He was also a fellow of the American Institute of Aeronautics and Astronautics and a chairman of the Los Angeles section of the American Institute of Aeronautics and Astronautics (AIAA), serving as vice chairman of the AIAA Aircraft Design Committee.

He received the Admiral Charles E. Weakley Award for a major contribution to the US anti-submarine warfare posture and was elected to the National Academy of Engineering.

Heppe received a bachelor's degree in mechanical engineering from Stanford University in 1944 and a master's degree in aeronautics from Stanford in 1945. He earned an aeronautical engineering degree from California Institute of Technology in 1947.

NORM NELSON (1988–86)

Nelson excelled throughout his whole life: from studying aeronautical engineering at the University of Cincinnati during the Great Depression, to starting his own toy company after World War II in Dayton, Ohio, to teaching weather at the University of Dayton during a brief stint in the 1940s.

Nelson was recruited by the CIA to work at the Lockheed Advanced Development Projects company, the Skunk Works, on the A12/YF-12/SR-71 Blackbirds with Kelly Johnson. He became a regular Lockheed employee and eventually served as chief of advanced design at the rotary wing branch.

In 1976 Nelson became program manager and chief engineer of the stealth fighter programs, working with Ben Rich. Out of this came the F-117 stealth fighter, which served so successfully in the first Gulf War. In 1984, he became vice president and general manager of the Skunk Works and held that position until he retired in 1988. He enjoyed many dedicated hours in his visionary role at Lockheed.

SHERMAN MULLIN (1990–94)

In 1959, Mullin joined the Lockheed Electronics Company as an electronics engineer, specializing in the design of military electronics systems.

Transferring to the Lockheed-California Company in 1968, Mullin played a major role in the development of the P-3 Orion and S-3 Viking anti-submarine warfare aircraft. He became chief engineer, P-3 aircraft, in 1974. From 1976 to 1980, he was P-3 program manager. He was director of planning and advanced programs from 1981 to 1982. In March 1982, Mullin was appointed a vice president in Advanced Development Projects, and program manager for the F-117A program.

In 1985, as vice president and general manager for Advanced Tactical Fighter programs at Lockheed Aeronautics, he directed the winning Lockheed/Boeing/General Dynamics team in developing advanced fighters for the USAF and US Navy.

Mullin is a fellow of the Institute for the Advancement of Engineering, an associate fellow of the American Institute of Aeronautics and Astronautics, senior member of the Institute of Electrical and Electronics Engineers and a member of several defense and scientific associations. Mullin is chairman of the Flight Test Museum Foundation and a trustee of the Naval Aviation Museum Foundation.

Mullin attended Princeton and several other universities. He completed the Stanford Executive Program in 1984. He served in the US Army from 1954 to 1957 and was on the faculty of the US Army Guided Missile School from 1955 to 1957.

JACK GORDON (1994–99)

Jack Gordon was named executive vice president of the Lockheed Advanced Development Company (LADC) when the company was created out of the Advanced Development Projects (ADP) division of Lockheed Aeronautical Systems Company (LASC). Gordon was ADP's assistant general manager from December 1987 and was named an LASC vice president in March of 1989.

Gordon joined ADP in 1964 as a propulsion engineer. During his career he participated in the design of the SR-71 Blackbird, the world's fastest- and highest-flying aircraft, the T-1 (the successor to the I1-21) and the F-117A stealth fighter. He held several executive positions in ADP, including deputy program manager on a classified program, ADP chief engineer and program director for the advanced tactical fighter.

Between 1979 and 1981 Gordon was assistant to Lockheed Corporation's vice president for engineering during an executive training assignment. He was responsible for coordination of Lockheed's corporate independent research and development effort.

Gordon earned bachelor's and master's degrees in mechanical engineering from Stanford University. In 1976 he received a second master's degree after completing the University of California, Los Angeles executive engineering program.

BOB ELROD (1999–2000)

Robert T. “Bob” Elrod came to town from Fort Worth, Texas, where he was executive vice president of Lockheed’s Tactical Aircraft Systems division. He came with the task of making the Skunk Works a leaner and more efficient company, one that could win the joint strike fighter competition.

The ascension of Elrod, whose experience is in managing production of F-16s, was a departure from the Skunk Works’ corporate culture. In the past, Skunk Works leaders rose from the engineering ranks, in the tradition of Kelly Johnson. It was a shift from top-secret, “hands off” management to a very visible, stockholder-driven culture that not all in the still largely secret organization were comfortable with.

After serving 21 years in the Air Force, Elrod moved to the Tactical Aircraft Systems Division of General Dynamics Company’s F-16 program in 1978.

“He brings together a wealth of program management experience spanning 21 years in the Air Force and another 21 years with the F-16 program,” Tim Griggs, a Lockheed Martin Skunk Works engineer, said at the time of Elrod’s appointment.

Elrod’s education is in business, not engineering. He holds bachelor’s and master’s degrees in business administration from the University of Oklahoma and Ohio State University, respectively.

GARY ERVIN (2000–01)

Ervin served as vice president and deputy of Air Combat Systems. He joined Northrop Grumman in that position in August 2001 after serving 22 years with Lockheed Martin Skunk Works in Palmdale, most recently as vice president, Advanced Development Projects.

Other assignments with Lockheed Martin included director, special technology: deputy program manager, F-117 stealth fighter, and director, X-35 joint strike fighter.

He has a Bachelor of Science degree in mathematics systems science from the University of California, Los Angeles.

FRANK CAPPUCCIO (2001–11)

Cappuccio joined the Skunk Works as an original member of the F-117 program with increasing professional responsibility, eventually serving as vice president and assistant general manager of the Research, Technology and Development Division.

In 1993, he joined Rockwell International, where he served as vice president of advanced programs, responsible for expanding the corporation's aerospace markets in operations analysis and radar signature suppression, as well as advanced weapon system design and development.

Cappuccio was assigned as vice president and program manager of the Joint Strike Fighter (JSF) program. Lockheed Martin won the JSF contract in November 2001. Key to this win was Cappuccio's leadership in integrating the technical and financial entities of BAE Systems and Northrop Grumman into a seamless F-35 program team.

Cappuccio holds an MBA from Adelphi University, a master's degree in mechanical engineering from Columbia University and a bachelor's degree in mechanical engineering from City College of New York.

AL ROMIG (2011–13)

Prior to joining Advanced Development Projects, Dr Romig spent more than 30 years with Sandia National Laboratories, operated by Sandia Corporation, a Lockheed Martin Company. His responsibilities there included the leadership of development and engineering activities providing science, technology and systems expertise in support of several key US programs.

During his time with Sandia he held a variety of management assignments including chief technology officer and vice president for science, technology and partnerships, and later served as the executive vice president, deputy laboratories director and chief operating officer responsible for all aspects of Laboratory business including the science and technology base supporting all Laboratory programs.

Romig has won numerous international prizes including the ASM Silver Medal for Outstanding Materials Research (1992). He has served on many influential government advisory councils and boards through either the US Government or the National Academies. He has also served on several industrial boards. He is also a senior member of the Institute of Electrical and Electronics Engineers, and has served as chairman of the United Way of

Central New Mexico.

Romig received his Bachelor of Science, Master of Science and doctorate degrees in materials science and engineering from Lehigh University in 1975, 1977 and 1979, respectively.

ROB WEISS (2013–18)

Prior to leading the Skunk Works, Weiss served as executive vice president and general manager of advanced strike and intelligence, surveillance and reconnaissance programs working across the Lockheed Martin Corporation to maximize key enterprise capabilities needed to capture and execute a selected set of major emerging programs. Prior to that position, he served as executive vice president and general manager of aeronautics operations where his more than ten years of program management experience proved critical in leading the team to deliver affordable, functional capabilities to aeronautics programs.

Weiss also served as aeronautics executive vice president for global sustainment in which he developed and directed strategies that grew the business to more than 30 percent of the company's business portfolio. As vice president of business development, he had responsibility for domestic and international new business for Aeronautics, achieving record sales.

Weiss served eight years as an officer in the US Navy before joining Lockheed Martin in 1985. He also served an additional 16 years in the Naval Reserve, retiring in 2000 with the rank of captain.

He is a graduate of the US Naval Academy and earned his Master of Science degree in systems management from the University of Southern California. He is a member of the Association of Naval Aviation, Air Force Association, Tailhook Association and the Logistics Officer Association.

JEFF BABIONE (2018–CURRENT)

Prior to leading the Skunk Works, Babione was the executive vice president and general manager, F-35 Lightning II program, at Lockheed Martin Aeronautics Company where he led all areas of the program for three F-35 aircraft variants for three US military services, eight international partner nations and multiple foreign military sales customers.

Babione served as vice president and deputy general manager, F-35 Lightning II program, from March 2013 to December 2015. Prior to joining the F-35 program, he served as vice president and general manager, F-16/F-22 Integrated Fighter Group.

A Lockheed Martin employee for more than 25 years, Babione has held a wide range of engineering and leadership positions, including F-22 chief engineer from 2006 to 2010 in which he was responsible for overall technical integrity of the world's first fifth-generation fighter program. Lockheed Martin and the Raptor Team were awarded the Collier Trophy for the most significant achievement in American aerospace in 2006.

He began his career with the Boeing Company in Seattle, where he worked as a structural engineer.

He holds a bachelor's degree in aerospace and ocean engineering from Virginia Tech, a master's degree in aerospace engineering from the University of Washington, and a master's in business administration from the University of Tennessee.

JIM GOODALL

How did a kid who grew up in the middle of a former apricot orchard that is now called Silicon Valley end up as one of the world's leading experts on the Lockheed Skunk Works, Area 51 and things that go "bump" in the night? It started with a handful of random events.

My very first exposure, and ultimately my love for all things Skunk Works and airplanes in general, began with a brief encounter that cemented my fascination with and love for airplanes.

The time was 1950/51. We lived in a duplex not far from what was the small San Jose Municipal Airport. I was about five years old and had gone to bed just before sunset. I was getting settled in when my Dad came into my room and said, "There's something coming, and I think you should see it." We went outside looking toward the Coast Mountains. Low over the peaks came not one, not two, but 24 Convair B-36 Peacemaker heavy bombers on the way to Travis AFB. I was hooked.

Move forward a few years and our family now called Los Altos, California, home. In 1954 my best friend's dad was commander of Moffett Field Naval Air Station (NAS), at Mountain View, California: at that time one massive base with over 400 aircraft assigned there. The Marines who guarded the base always referred to Danny and myself as "Captain Smith's son and that friend of his!" We had the run of the place.

On this particular day, Danny said he had something to show me. We headed over to the Big Hangar 1 and went to the far end nearest to the Bay. There was an area that was roped off with curtains shielding something very special behind the veil of secrecy. There were no guards, just a sign that read "Off Limits." Too tempting for a couple of seven-year-olds.

Behind the curtain was the still secret Lockheed XF-104 Starfighter. We walked around in awe, as this was right out of science fiction. Danny then threw down the gauntlet; "Get in the cockpit!", so I did. Danny closed the canopy and the latch malfunctioned. I was stuck!

We both tried to open it for a few minutes when I began to panic. The only way out was to call the Marines and the Shore Patrol; boy, were they pissed or what! Nearly 70 years later, my butt still hurts.

Fast forward to March 1964. I was an 18-year-old airman second class (name of the rank was changed for PC reasons) in the Air Force and was sent TDY (temporary duty) to Edwards AFB to install and maintain their ground base telemetry system for three Category One testing programs. The first two were public knowledge: the YC-141 Lockheed Starlifter and the North American XB-70 Valkyrie; plus there was a classified program. That program was Kelly Johnson's ultimate interceptor, the Mach 3+ YF-12A.

On 10 March 1964, at approximately 3.15pm, I saw what was to change my life forever. On the XB-70 test pad was what I first thought was the North American X-15 rocket plane, but the people were way too small. Much to my amazement, I had my first glimpse of Kelly's incredible Mach 3+ Blackbird in full afterburners, the YF-12A. I've never been the same!

In the spring of 1968, via the US Postal Service, I formally asked Lockheed, the USAF, the DoD and the CIA for unclassified photos of the SR-71 on the ground or in the air. I was willing to pay the published rate for color 8x10s. I was turned down and never received any of the photos I had requested.

The year 1975 was a watershed year; my dear friend, John Andrews, introduced me to an aviation character named John Lear, the son of the "Father of the Lear Jet," William Lear. It was through Lear that we discovered a path to the top of White Sides Mountain, 2,000ft above our camp site location. On top of the mountain was an unobstructed panoramic view of the once very secret Area 51.

November 1988: after seeing and photographing the Lockheed Skunk Works F-117 for the first time along the fenceline at Tonopah Test Range, John Lear and I headed back to Las Vegas. We arrived at John's home about 9.15pm, and ten minutes later a young man showed up. I had print film that needed to be processed and all of the FotoMats (way before digital photography) were closed. I wouldn't know if any of my images were any good until well into the next day. John's friend told me he had a Kodak C-41 film processor at his home. That friend was a guy named Bob Lazar.

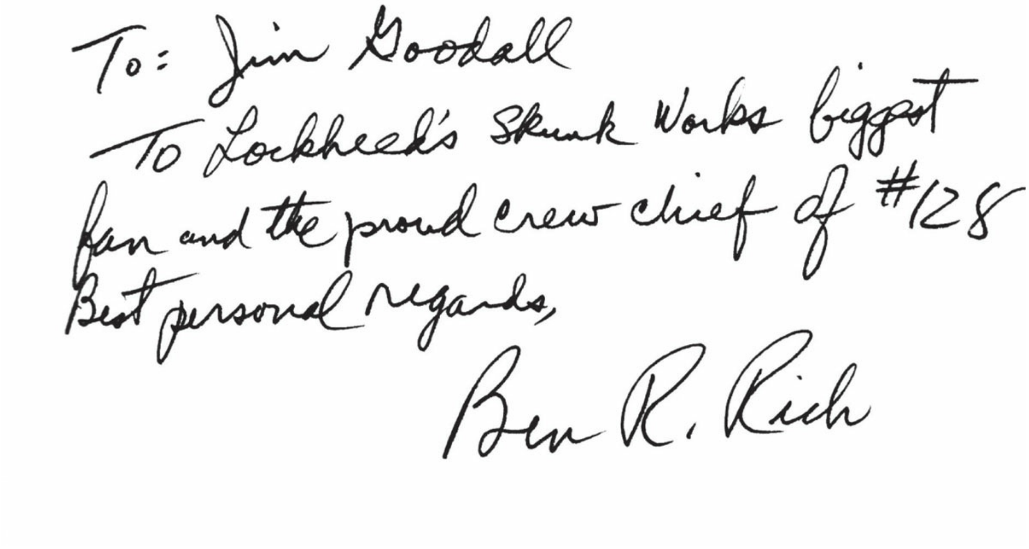
We needed to head back to John's friend's home to process some film. There in living color was the very first non-DoD or Lockheed photo of the first operational stealth fighter, the F-117A Senior Trend.

Had the Air Force, Lockheed, DoD and the CIA honored my photo requests in 1968, I would have been happy to just move along. But, as with all things government, their unofficial "official" policy was to not cooperate; so, I started digging, and the more I dug, the more I found out and the deeper I dug.

I would not be where I am today, in the field of spooky programs, if our government had given me what I wanted in 1968. I would have remained happy and my name would never have been associated with Area 51, the Blackbirds, the F-117 or the Skunk Works. And Ben Rich and I would never have been friends.

That's how a young kid from Los Altos ended up 60+ years later being an expert on much of what has come out of the brilliant minds of the men and women at the Lockheed Martin Skunk Works.

Cheers,
Jim Goodall



To: Jim Goodall
To Lockheed's Skunk Works biggest
fan and the proud crew chief of #128
Best personal regards,
Ben R. Rich

A photo of the author, MSgt James C. Goodall, USAF (ret) in the cockpit of an SR-71A at Beale AFB, CA, in the late 1980s. (Author's collection)

ACKNOWLEDGM

If it were not for the design genius of C. L. “Kelly” Johnson I would have never started my 50+ year quest to find all things Blackbird.

Without Kelly’s talent and that of his entire Skunk Works team, I would have never met all of the incredible men listed in my acknowledgments; for that I will be always grateful.

After my very first encounter with the Blackbird on 10 March 1964, never in my wildest dreams would I have believed that it would take me to this point in my life.

With the help of all these people, I now have a library of photos and documents on the Blackbird only rivaled by the Skunk Works extensive collection and maybe a few others.

And to the men and women who designed, built, worked on, flew and supported the Blackbird program from its inception to the very end … THANK YOU.

Dave Allison – USAF
Robert Archer: here
Ben Bowles – USAF
Buddy L. Brown – ADP
Stu Brown
Ron Bullard – USAF
Fred Carmody – ADP
Glenn Chapman – USAF
Ken Collins – CIA
Joe Daley – Pratt & Whitney
Larry Davis: here
John Dibbs: here
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Ken Koller: here
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Tony Landis
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Brian “Buck” C. Rogers – USAF
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